THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. 44 APRIL 1951 Part 1

CONTENTS

	PAGE
ACCEPTANCE TESTING OF COAXIAL PAIRS FOR THE INLAND TRUNK NETWORK—R. E. Taylor, A.M.I.E.E., and R. J. Turner, B.Sc.(Eng.), A.M.I.E.E.	1
A NEW PORTABLE GENERATING SET FOR MANHOLE LIGHTING—B. C. Hill, B.Sc.(Eng.), A.M.I.E.E., and E. E. M. Smith, A.M.I.E.E.	7
INTRODUCTION TO ELECTRONIC EXCHANGES—TRUNKING AND SELECTION SYSTEMS—T. H. Flowers, M.B.E., B.Sc.(Eng.), M.I.E.E.	10
WHITEHALL GARDENS P.A.B.X.—F. T. Perkins	15
ALTERATIONS TO H.M.T.S. ARIEL'S CABLE PAYING-OUT GEAR	17
THE SINGLE-COMMUTATION DIRECT CURRENT SIGNALLING AND IMPULSING SYSTEM—S. Welch, M.Eng., A.M.I.E.E., and B. N. Horsfield, A.M.I.E.E.	18
THE NEW LONDON RADIO-TELEPHONY TERMINAL—C. W. Sowton, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E., and D. B. Balchin, B.Sc.(Eng.), A.M.I.E.E.	25
AN APPLICATION OF EQUALISER CURVES TO THE DESIGN OF TWO-TERMINAL NETWORKS—P. W. Seymour, A.M.I.E.E.	31
THE MANCHESTER-EDINBURGH TELEVISION RADIO RELAY SYSTEM	33
COMMONWEALTH TELECOMMUNICATIONS	35
NOTES AND COMMENTS	36
INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS	38
REGIONAL NOTES	39
JUNIOR SECTION NOTES	43
STAFF CHANGES	46
BOOK REVIEWS	24, 30, 32, 34, 45, 48

Price 1/6 net

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

STUDY AT HOME

You Can Have a College Training For a Few Shillings Monthly

IN YOUR SPARE TIME

CITY and GUILDS
(Telecommunication)
EXAMINATIONS

The most progressive and most successful Correspondence College in the world

To every student we send a written Guarantee of Tuition until the examination is actually passed

Our tuition is so graded that each stage is reached without difficulty.

Personal attention is given to every student.

FULL PARTICULARS AND ADVICE SUPPLIED FREE.

WE TEACH BY POST IN ALL PARTS OF THE WORLD.

The Bennett College Limited

Dept. 24, THE BENNETT COLLEGE, SHEFFIELD

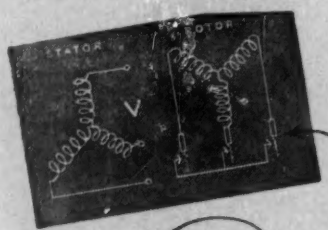
"ANACOS" REGD.

TELEPHONE & TELEGRAPH WIRES
IN COPPER, CADMIUM-COPPER & BRONZE

"the right connection"

FS

FREDERICK SMITH & COMPANY
(Incorporated in The London Electric Wire Company and Smiths, Limited)
ANACONDA WORKS, SALFORD 3, LANCS.
Phone: Blackfriars 8701 (9 lines) • Grams: "Anaconda," Manchester



A.C. Polyphase Wound Rotor - Rotor Rheostat.

FOR EVERY PHASE OF ELECTRICAL WORK

The British Electric Resistance Co. Ltd. can answer the multitude of resistance problems that beset the electrical circuit designer. For twenty years Berco resistances have been giving reliable and steadfast service, and the Berco range is designed to meet every requirement.

Berco engineers are specialists in resistance design and their knowledge is at your disposal.

BERCO

RESISTANCES

THE BRITISH ELECTRIC RESISTANCE CO. LTD.
Queensway, Ponders End, Middlesex
Telephone: Howard 1492 Telegrams: Vitrohm, Enfield
BR2033-80

QUANTITY
but not MASS production

Each transformer we design is produced with the infinite care and accuracy of a well-tailored garment.

The results regularly achieved bring us many letters of appreciation and congratulation from Home and Overseas.

SAVAGE TRANSFORMERS OF DEVIZES LIMITED

SAVAGE TRANSFORMERS LTD. • NURSTED ROAD, DEVIZES, WILTS.

SUPPLEMENT
TO THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

CONTENTS

C. & G. EXAMINATIONS, 1950

TELECOMMUNICATIONS (Principles) III, 1950 (*Continued*)

LINE PLANT PRACTICE II, 1950

LINE TRANSMISSION II, 1950

TELEPHONE EXCHANGE SYSTEMS III, 1950

TELEGRAPHY II, 1950

Vol. 44 April 1951 No. 1

CITY AND GUILDS OF LONDON INSTITUTE EXAMINATIONS, 1950

QUESTIONS AND ANSWERS

The following answers generally give more detail than would be expected in the time available under examination conditions but, to conserve paper, arithmetical working has been abbreviated.

TELECOMMUNICATIONS (PRINCIPLES) III, 1950 (*continued*)

Q. 7. The anode current/anode voltage characteristics of a triode valve are given in the accompanying table :—

Grid Volts	Anode Current (mA)				
	0	−3	−6	−9	−12
Anode Volts					
40	1·75	—	—	—	—
60	4·2	0·8	—	—	—
80	8·0	2·0	—	—	—
100	12·8	4·2	1·0	—	—
120	18·0	8·0	2·4	—	—
140	—	12·9	5·0	0·9	—
160	—	17·8	8·8	2·8	0·2
180	—	—	13·8	5·7	1·2
200	—	—	18·0	10·0	3·2

The valve is to be used in the output stage of an amplifier which is feeding a non-reactive load of 600 ohms. If the e.m.f. of the anode battery is 120V and the peak value of the sinusoidal alternating voltage applied to the grid is 4V, determine—

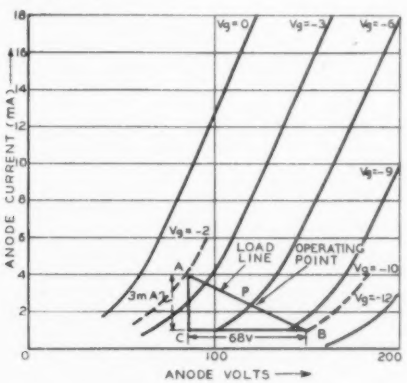
(a) the most suitable operating point for the valve as a Class A amplifier,

(b) the transformer ratio for maximum transference of power to the 600-ohm load,

(c) the magnitude of this maximum power,

(d) The overall voltage amplification of the stage, using the transformer in (b).

A. 7. The anode current/anode volts characteristics have been plotted in the sketch.



The valve will operate most satisfactorily as an amplifier when even the peak value of the voltage applied to the grid does not cause grid current to flow. In this case, therefore, the grid bias should be at least −4·0V. Since the characteristic for $V_g = -4{\cdot}0$ is not given, it will be evident that the least amount of interpolation will be required if the grid bias is fixed at −6·0V, so that the operating point will be on the $V_g = -6{\cdot}0$ characteristic. Portions of the anode current/anode volts characteristics for $V_g = -2{\cdot}0$ and $V_g = -10$ have been sketched in by interpolation on the sketch. The operating point, P, has been found such that the load line, AB, has the maximum length when PA/PB = 11/9, i.e., the amount of second harmonic distortion introduced by the valve does not exceed 5 per cent.

For these conditions :—

Anode Volts = 120 V.
Grid Bias = −6 V.
Anode Current = 2·4 mA.

Thus, the E.M.F. of the anode supply must be 120V, the internal resistance of this supply and connections must be negligible, and the non-reactive load must be coupled to the anode circuit by means of a transformer, the anode winding of which has negligible resistance.

Again, the maximum swing of anode current will be 3·0 mA, and this should be caused by a swing in anode voltage of 68V. Thus, the non-reactive load of 600 ohms should appear as a resistance in the anode circuit, which has a value of :—

$$R = \frac{V}{I} = \frac{68}{3{\cdot}0 \times 10^{-3}} = 22{,}666 \text{ ohms.}$$

For this to be so, the ratio of the step-down output transformer must be :—

$$\sqrt{\frac{\frac{68}{3 \times 10^{-3}}}{600}} = \underline{6{\cdot}15}$$

Assuming that the alternating components of anode current and voltage are sinusoidal, their effective values must be $1/(2\sqrt{2})$ the corresponding swings. Thus,

$$i_a = \frac{3{\cdot}0}{2\sqrt{2}} \text{ mA.}$$

$$v_a = \frac{68}{2\sqrt{2}} \text{ Volts.} = 24 \text{ Volts.}$$

Hence, if there are no losses in the output transformer, the output power will be :—

$$i_a \cdot v_a = \frac{3{\cdot}0}{2\sqrt{2}} \times \frac{68}{2\sqrt{2}} = \frac{204}{8} = \underline{25{\cdot}5 \text{ mW.}}$$

The output voltage will be

$$\frac{24}{6{\cdot}15} = 3{\cdot}9 \text{ Volts. R.M.S.}$$

This is produced by a sinusoidal grid voltage which has a peak value of 4·0, or an effective value of $4{\cdot}0/\sqrt{2} = 2{\cdot}83$ Volts.

Hence, the overall voltage amplification of the stage will be

$$\frac{3{\cdot}9}{2{\cdot}83} = \underline{1{\cdot}38.}$$

Q. 8. Explain what is meant by the insertion loss of a network and indicate how this loss is affected when the value of the terminating impedances is reduced from the image impedance to one-half of this value. Calculate, from first principles, the insertion loss of the network shown in Fig. 4 when it is connected between equal terminal non-reactive impedances of—

(a) 200 ohms,

(b) 800 ohms.

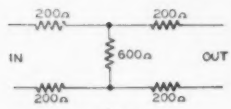
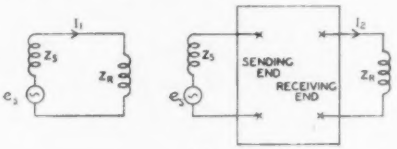


Fig. 4

A. 8. The insertion loss of a network is the loss, expressed in decibels, caused by the insertion of the network into a transmission system.

For example, referring to sketch (*a*), the current, I_1, flowing in the



(*a*)

load impedance, Z_R, when the network is not included between the source and its load, is given by :—

$$I_1 = \frac{e_s}{Z_R + Z_R}$$

When the network is included, suppose the current flowing in the load is now I_2. Then, the insertion loss (or gain) caused by the network is given by :—

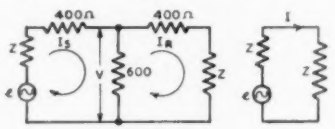
$$20 \log_{10} \frac{I_1}{I_2}$$

When a network is terminated at its receiving end by its image impedance, Z_{I2}, the impedance measured across the sending end terminals will be the sending end image impedance Z_{I1}.

Hence, if the internal impedance of the source is also Z_{I1}, there will be the maximum transfer of power from the source to the network. But, under these conditions, the receiving end terminals of the network will be matched to Z_{I2}, so that maximum transference of power occurs at this end also. The loss in power between the source and the load will, therefore, be minimum.

For any other condition of terminal impedances, for example, when they are reduced to one-half the respective image impedance, the insertion loss will be greater. The precise amount will depend on the particular network under consideration.

In the case given, referring to sketch (*b*) :—



(*b*)

$$I = e/2Z$$

$$\text{and } V = e - (Z + 400)\, I_S = (400 + Z)\, I_R = 600\,(I_S - I_R)$$

$$\therefore \quad I_S = \frac{e - (400 + Z)\, I_R}{Z + 400} = \frac{e}{Z + 400} - I_R$$

$$\text{Hence, } (400 + Z)\, I_R = 600 \left\{ \frac{e}{Z + 400} - I_R - I_R \right\}$$

$$I_R\,(400 + Z + 1{,}200) = \frac{600e}{Z + 400}$$

$$\text{or } I_R = \frac{600e}{(Z + 400)\,(Z + 1{,}600)}$$

$$\text{and } \frac{I}{I_R} = \frac{(Z + 400)\,(Z + 1{,}600)}{1{,}200\,Z}$$

When $Z = 800$ ohms,

$$\frac{I}{I_R} = \frac{1{,}200 \times 2{,}400}{1{,}200 \times 800} = 3{\cdot}0$$

$$\text{Insertion loss} = 20 \log_{10} \frac{I}{I_R} = 20\ (0{\cdot}4771)$$

$$= \underline{9{\cdot}54 \text{ db.}}$$

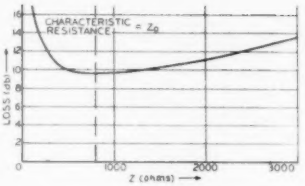
When $Z = 200$ ohms,

$$\frac{I}{I_R} = \frac{600 \times 1{,}800}{1{,}200 \times 200} = 4{\cdot}5$$

$$\text{Insertion loss} = 20\ (0{\cdot}653)$$

$$= \underline{13{\cdot}06 \text{ db.}}$$

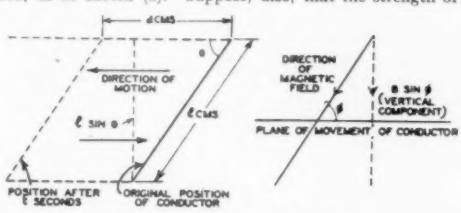
The graph of insertion loss against values of Z has been plotted in sketch (*c*). From this it will be observed that the loss is minimum when $Z = 800$ ohms, which is the characteristic resistance of the network. When Z is 400 ohms, the insertion loss of this network is about 1 db greater than this minimum.



(*c*)

Q. 9. Derive an expression for the force experienced by the coil of a permanent magnetic, moving coil receiver, when it carries a direct current. Assume that the flux-density in the gap is uniform. Thence, indicate graphically how the applied force varies with frequency, when a sinusoidal alternating voltage of constant amplitude is applied across the coil. On the same graph include an approximate characteristic of a commercial moving-coil receiver, showing the variation with frequency of the ratio of acoustic pressure to voltage input. Give reasons for any difference in shape of the two curves.

A. 9. Suppose that a straight conductor of length l cms., which is carrying a current of I amperes, is moving with a uniform velocity, v cms./sec., in a magnetic field at an angle θ to the direction of motion, as in sketch (*a*). Suppose, also, that the strength of the



(*a*) (*b*)

magnetic field is B and its direction is inclined at an angle, ϕ, with the plane of motion of the conductor, as in sketch (*b*).

In t seconds the conductor will have moved a distance, d cms., and, as a result, $B\,d\,l \sin\theta \sin\phi$ lines of magnetic force will have been linked with its circuit.

The E.M.F. induced in the circuit is :—

$$e = \frac{B\,d\,l \sin\theta \sin\phi}{t} \times 10^{-8} \text{ Volts.}$$

If F dynes is the force which must be applied to move the conductor, we have

Work done on conductor = Electrical Energy given to circuit

$$\therefore F \times d = e\,I\,t \times 10^7 \text{ ergs.}$$

$$\text{i.e., } F = B\,I\,l\ 10^{-1} \sin\theta \sin\phi \text{ dynes.}$$

When $\theta = \phi = 90°$, $F = B\,I\,l/10$ dynes.

The direction of this force can be determined by Fleming's Left-Hand Rule.

Let the diameter of the moving coil be D cms., and suppose it has N turns of wire which move in a uniform radial field of B lines /sq. cm. Length of wire on coil $= N \times \pi D$ cms.

$\therefore$ Force on coil, when carrying a direct current of I amperes,

$$= \pi\,B\,D\,N\,I/10 \text{ dynes.}$$

Under alternating current conditions, the impedance of the coil is $Z = R + j\omega L$.

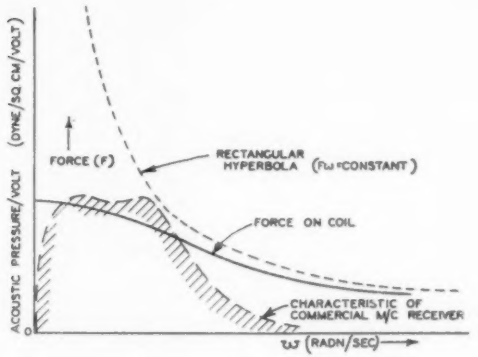
At very low frequencies $R \gg \omega L$. $\therefore Z \triangleq R$, whereas at high frequencies $Z \triangleq \omega L$ and then, $I = V/Z = V/\omega L$

$$\text{and } F = \frac{\pi BDNV}{10\ \omega\ L} \text{ or } F \propto \frac{1}{\omega}$$

Thus, the force experienced by the coil will vary, as shown in sketch (*c*), from a value of $BlI/10 = \pi BDNV/10R$ at zero frequency and become asymptotic to the rectangular hyperbola :—

$$F\omega = \frac{\pi BDNV}{10L}$$

An approximate characteristic of a good commercial moving-coil receiver, when held to an artificial ear, has been included on sketch (*c*). This differs in shape from the force characteristic for



(*c*)

the reason that the acoustic pressure, p, developed in the cavity of the artificial ear depends on the velocity, v, of the receiver diaphragm, which is governed not only by the force applied to the diaphragm by the moving coil but also by the overall mechanical impedance of the diaphragm, thus :—

$$v = \frac{F}{Z} = \frac{F}{r + j\left(\omega m - \frac{S}{\omega}\right)} \text{ cm./sec.}$$

where r is the coefficient of resistance,

m is the equivalent mass,

and S is the stiffness.

At low frequencies Z is high ($Z \triangleq r$). $\therefore$ v and p are small. Again, at high frequencies Z is high ($Z \triangleq j\omega m$). $\therefore$ v and p are small. Intermediately, resonances may occur due to the mechanical properties of the diaphragm itself and to the loading impressed on it by air cavities in front and behind.

Q. 10. *Describe the main features of inductors designed to have minimum external magnetic and electric fields.*

Explain clearly how any resulting field can be further reduced by external screening when the winding carries —

(*a*) *a low frequency current,*

and (*b*) *a high frequency current.*

A. 10. For a circuit to have self-inductance, the lines of magnetic force produced by any current flowing in the circuit must be linked with it. Thus, if an inductor is to have the minimum external field, it follows that throughout their entire length the lines of magnetic force must be confined to the core which constitutes a closed magnetic circuit around which are wound the turns of wire forming its electrical circuit.

One method of achieving this consists of equally spaced turns of insulated copper wire wound round a toroidal iron core which has constant cross-sectional area and uniform, high axial permeability.

Any inductance included in a circuit should be controllable; that is, the inductance should be confined to inductors themselves, the remainder of the circuit having the least possible self-inductance. Hence, the actual connections to the turns of wire on an inductor should be non-inductive, e.g., a closely twisted pair of insulated copper wires having a constant lay.

In practice, despite careful manufacture, even closed core inductors still exhibit a small external magnetic field. This can be more or less confined by some form of magnetic screening. When designing such screens, it must be remembered that the magnetic flux, which it is desired to enclose, originates from the current flowing in the inductor winding. Inductors are only required in circuits which carry alternating current so that some, if not all, of the leakage magnetic flux will be alternating. If this alternating flux cuts a conductor, an E.M.F. will be induced in it and cause a current to flow when a continuous conducting path is provided. Under these conditions, the inductor becomes the primary winding of a transformer which has a loosely coupled secondary. Any power expended in this secondary will be reflected in the primary and will be accounted for by an increase in the effective resistance of the inductor winding.

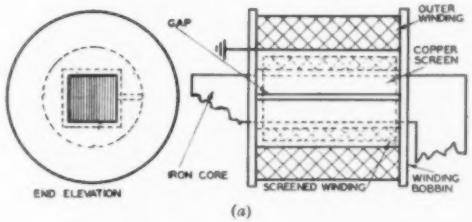
Thus, the screen provided for an inductor which carries low-frequency alternating currents may be a closed container of high permeability material (so that the magnetic flux would prefer to travel in the screen rather than in the air beyond) having high resistivity in the direction in which any eddy currents would flow and low hysteresis loss. A suitable material is Stalloy.

For higher frequencies, the screen should be formed from insulated fine particles of high permeability material, which has low hysteresis, compressed with a suitable binder into a solid. Mumetal dust is satisfactory for such screens which can be effective up to very high frequencies.

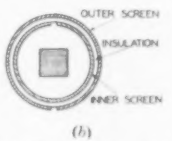
The thickness of the screens provided will depend on the degree of screening required.

An alternative method of screening inductors carrying high-frequency alternating currents is by means of a container made from some good electrical conductor, e.g., copper, so arranged that no closed circuit is provided in a plane at right-angles to the main flux path. By this method the effectiveness of a screen depends solely on the ease with which eddy currents will flow in the screen. This can only be achieved if the material of which the screen is made is a good electrical conductor which will also ensure low power loss, due to these eddy currents. Again, when good electrical conductors are used for magnetically screening inductors, the inductors themselves should be designed to have the smallest leakage field possible.

The field of electric force from an inductor will be determined by the potential of its conductors relative to earth, which will depend on the potential of one terminal and the potential difference between the terminals of the inductor winding. The potential difference across an inductor is proportional to the impedance of the winding. The unwanted resistance component should be reduced as far as possible, therefore, by winding the inductor with a low-resistance conductor on a core which has low hysteresis and eddy current losses, and ensuring that the leakage magnetic flux is a minimum. In order to localise the electric field to the precincts of the inductor, an earth-connected screen of good conducting material should enclose it. As with magnetic screens, so in this case, no continuous conducting path should be provided in a plane at right-angles to the main flux path. For example, the electric screen between the windings of a transformer could be a copper cylinder with an axial cut, as in sketch (*a*). The width of the cut and the insulation of the gap must withstand the voltage across the gap, due to any E.M.F. induced in the screen. Such a screen is not complete. Improved screening can be obtained by fitting a similar screen outside the former and insulated from it, provided the gaps are not adjacent (sketch (*b*)).



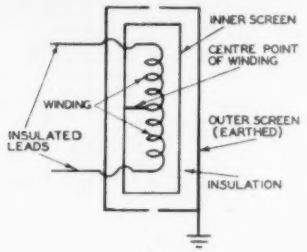
(*a*)



(*b*)

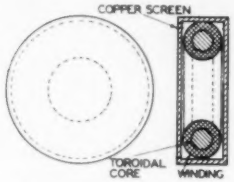
If the terminals of the inductor or transformer winding are to be balanced about earth and yet insulated from it, the inner of the above screens should be connected to the centre point of the winding, while

the outer only should be earth-connected, as indicated in sketch (*c*).



(*c*)

It will be realised that these electric screens are also magnetic screens. Thus, a complete cylindrical copper box will form a combined screen for a toroidal inductor (sketch (*d*)).



(*d*)

LINE PLANT PRACTICE II, 1950

Q. 1. To what forces is a large concrete manhole in the carriageway subjected? Explain briefly how the reinforcement is positioned to accept the induced stresses.

A. 1. A manhole in the carriageway is subject to the following loadings:—

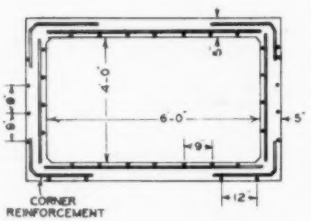
(*a*) (i) *Earth pressure on the side and end walls.* This is the normal lateral force of the earth as resisted by a retaining wall. It is a maximum in soils of low cohesion or under conditions of flooding.

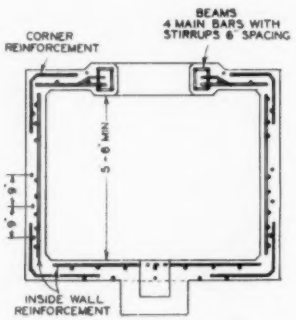
(ii) Depending on the depth of the manhole there will also be a force on the roof due to the dead weight of earth above.

(*b*) *Pressure transmitted through the earth arising from nearby road traffic.* This produces a loading mainly horizontal on the walls and mainly vertical on the roof. The lateral wall loading at any depth is at a maximum when the traffic load is at a distance from the wall about equal to the depth. The vertical loading is evidently at a maximum when the traffic load is directly above the area concerned. When the traffic load passes over the manhole cover the full load is transmitted to the beams employed to support the cover.

(*c*) *Loads on anchor irons when cabling is in progress.* These are greatest under severe cabling conditions and when the load on the anchor iron is in a direction perpendicular to the wall.

(*d*) *Wall loadings due to cable bearers.* These may be resolved into lateral and vertical loadings on the walls. The vertical loadings induce no tensile loadings in the wall and are usually negligibly small.





The loadings given in (*a*), (*b*), (*c*) and (*d*) combine together to give lateral loadings on the end and side walls of the manhole and vertical loadings on the roof. The walls being monolithic at their join must be reinforced near the outside surface at their junctions and near the inside surface at the middle sections. The length and disposition of the reinforcement must extend at least to the point of contraflexure (i.e., where the bending moment changes sign). In practice, for convenience in fixing reinforcement and for standardisation, a typical arrangement adopted is as shown in the sketch.

Q. 2. A 3-way duct is laid with 2 ft. of cover from the surface of a road consisting of 4 in. of "macadam specially treated" (i.e., macadam treated with bitumen) not laid on a concrete foundation. Describe the filling-in and the temporary and permanent reinstatement processes on the trench (ignoring work at jointing chamber positions), giving reasons for the actions described.

A. 2. Assuming that the 3-way duct has been checked for alignment and the depth of cover has been recorded, the first operation is to pack the sides of the duct with selected soil, free from large stones. The soil is placed around the sides of the duct and carefully, but solidly, punned with a suitable punner, usually a poling board trimmed at one end so that it can be easily handled. This type of punner is necessary because the restricted space at each side of the duct is too narrow for an ordinary earth rammer to be used. Care must be used in this operation so that the ducts are not displaced during punning and to maintain their position it is usual only to fill in around the sides of the duct level with the top of the duct.

When the space at the sides of the duct has been thoroughly filled and consolidated, a layer of selected soil, free from stones, is placed over the duct and carefully hand-punned to a thickness of 3 in. when consolidated. Soil free from stones is stipulated for this first layer to prevent damage to the ducts during the hand-punning operation. The remaining excavation is then filled up with the excavated soil in layers of 6 in. to 9 in. Each layer must be well punned and in order to obtain this, if hand-punning is being employed, it is essential to have only one shoveller to three punners.

Consolidation must be carefully carried out when either hand or mechanical rammers are used, and care must be taken to see that the blows given by the foot of the rammer overlap through the whole operation of punning. If water is available the trench filling should be watered to aid consolidation. The soil and grades of stone removed from the trench during excavation should be replaced in the same order. In this case the top surface, i.e. the disturbed macadam, which should have been carefully preserved, is now replaced in the trench near to the surface and thoroughly consolidated, care being taken not to leave large stones immediately on the surface. The trench is finally given a covering of fine material (separated from the large top surface soil) to fill any voids and as a binding agent to the temporary surface. The temporary reinstatement of the trench should be left level with the surrounding surface.

The permanent reinstatement of the trench follows as soon as it can be seen from periodic inspection that the temporary reinstatement satisfactorily withstands the action of weather and traffic. Anything from a few days to a month or more may be necessary for "weathering" of the trench, depending on the nature of the subsoil. When permanent reinstatement can proceed the temporarily reinstated surface is re-excavated to a depth comparable with the surface to be reinstated, in this case, 4 in. The trench is then given a final punning to reveal any soft spots, which are filled and re-rammed. The edges of the road surface adjacent to the trench are then trimmed back 3 in. on either side, the new edges of macadam surface are given an application of bitumen primer before the new macadam material is placed in the trench and 3 in. wide "margin" to the required thickness and rolled in either by means of a heavy hand-roller or a motor-roller. The reinstated area is finally given a finish by dusting over with cement or fine sand.

Q. 3. *The two* 40-*lb. wires serving a subscriber are* 60 *yards long and are tensioned to* 70 *lb. each. Assuming the fixing at the house to be rigid, calculate the increase in tension if—owing to the fixing of other wires—the pole is moved* 1 *in. in the direction away from the house.*

(*Assume E for the wire is* 18×10^6 *lb./sq. in. The diameter of a* 40-*lb. wire is* 0·051 *in.*)

A. 3. Using the relationships

$$d = \frac{wL^2}{8T} \quad \ldots\ldots(1)$$

$$\text{and } l = L + \frac{8d^2}{3L} \quad \ldots\ldots(2)$$

where d = dip; L = span length; T = tension in the wires; w = weight per ft. run of each wire; l = length of the sagging wire; and E = Young's Modulus = stress/strain,

and substituting for d in (2)

$$l = L + \frac{8w^2L^4}{3L \,.\, 64T^2} = L + \frac{w^2L^3}{24\,T^2} \quad \ldots\ldots(3)$$

Now, if T_1 is the tension in the wire initially and T_2 is the tension in the wire after the pole has moved 1 in., the change in length of the wire may (from (3)) be expressed as:—

$$\left[L + 1'' + \frac{w^2(L + 1'')^3}{24T_2^2}\right] - \left[L + \frac{w^2L^3}{24T_1^2}\right]$$

But 1 in. is negligible in comparison with L and the change in length of the wire may be written

$$1'' + \frac{w^2L^3}{24}\left(\frac{1}{T_2^2} - \frac{1}{T_1^2}\right) \quad \ldots\ldots(4)$$

But this change in length = the elastic stretch of the wire

$$= (T_2 - T_1)\frac{L}{Ea}$$

Thus,

$$1'' + \frac{w^2L^3}{24}\left(\frac{1}{T_2^2} - \frac{1}{T_1^2}\right) = (T_2 - T_1)\frac{L}{Ea}$$

Inserting values, $a = \frac{\pi}{4} \times 0{\cdot}051^2 = 0{\cdot}002$ sq. in.

$$wL = \frac{40 \times 60}{1760} = 1{\cdot}362$$

$$L = 180 \times 12 = 2{,}160 \text{ in.}$$

$$\text{Hence, } \frac{L}{Ea} = \frac{2160}{0{\cdot}002 \times 18 \times 10^6} = 0{\cdot}06$$

$$\text{and } 1 + \frac{1{\cdot}362^2 \times 2160}{24}\left(\frac{1}{T_2^2} - \frac{1}{4900}\right) = (T_2 - 70) \times 0{\cdot}06$$

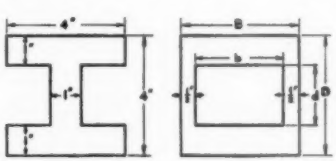
$$\text{i.e. } T_2^2\,(T_2 - 86) = 2800$$

By slide rule or trial and error, $T_2 = 86{\cdot}4$ lb.

and the increase in tension, $T_2 - T_1 = 86{\cdot}4 - 70 = \underline{16{\cdot}4 \text{ lb.}}$

Q. 4. *A* 4 *in.* × 4 *in. steel beam may be considered as being made up of two rectangular flanges each* 4 *in.* × 1 *in., connected by a rectangular web* 2 *in.* × 1 *in. This beam is freely supported at its ends, has a span of* 10 *ft. and has concentrated loads of* 4 *tons each at points* 2 *ft. from each support. Calculate the maximum bending moment and the maximum tensile stress in the beam.*

A. 4. The beam which is shown in sketch (*a*) may clearly be redrawn as in sketch (*b*). The Moment of Inertia of this section is



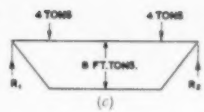
(*a*) (*b*)

$$I = \frac{BD^3}{12} - \frac{bd^3}{12}$$

$$= \frac{4 \times 4^3}{12} - \frac{3 \times 2^3}{12} = 19\tfrac{1}{3} \text{ in.}^4$$

By symmetry, as indicated in sketch (*c*), $R_1 = R_2 = 4$ tons.

Hence maximum bending moment $= 4 \times 2$ ft. tons $= \underline{8 \text{ ft. tons.}}$



(*c*)

Using the relationship $M/I = f/y$

Where M = Max. BM.

I = Moment of Inertia of Section

f = Max. stress

y = Dist. of max. stress from neutral axis.

$$f = My/I = \frac{(8 \times 12 \times 2240) \times 2}{19\frac{1}{3}} = \underline{22{,}300 \text{ lb./sq. in.}}$$

Q. 5. *What are the factors that control the strength of concrete and in what way does each affect it? What steps are taken during the mixing and placing operations to control these factors?*

A. 5. The quality of finished concrete is dependent on (*a*) the proportions of the constituent materials; (*b*) their quality and suitability; (*c*) their mixing, placing and curing.

Under (*a*) a typical mix is, by volume, one measure of cement, two of fine aggregate (sand) and four of coarse aggregate. Richer mixes (more cement) can give increased strength and density at greater cost, whilst leaner mixes (less cement) are cheaper but weaker, less impervious and resistant to chemicals and weather, although still suitable for many purposes. A typical water content for the mix first quoted would be about 5-6 gallons of water per cu. ft. of cement.

An excess of cement (a rare fault since it is the most expensive constituent) will lead to a powdery surface of poor wearing quality. A deficiency of cement causes weakness, porosity, liability to frost attack and early disintegration. Insufficient water (a rare fault) up to a point may allow high strength but produce a stiff and unworkable mix. Beyond this, if the water is not enough to hydrate the cement fully the concrete will be visibly imperfect and useless. Too much water (probably the most common fault of all in concrete making) allows easy workability but leads to serious loss of strength, high porosity and general impermanence. Variations in the quantities of aggregates together are deducible from the relative proportions of cement and water as discussed. But changes in the relative quantities of fine and coarse aggregates specified for optimum strength generally cause weakness by affecting the uniformity of grading, by which particles of sizes varying between the finest and the coarsest should be present reasonably uniformly throughout the mix.

Under (*b*) the cement should be of the requisite quality sufficiently specified in a British Standard. It should be fresh, dry and clean before use. Aggregates should be clean, durable, structurally sound and free from adherent coatings and organic matter. The grading and proportion of fine and coarse aggregates, which govern the amount of mixing water needed for a given consistency, must permit the specified water/cement ratio. Fine aggregate should be of the nature of cubes rather than flakes, hard and impervious. Water should be of drinking standard.

Under (*c*) mixing should be thorough—first dry—then by gradual addition of the water via a sprinkler. Machine mixing should occupy about 2-3 minutes but longer is permissible. Placing of the concrete must not involve throwing from a height for fear of separation of the aggregates and attention must be given to ensure consolidation and intimate contact with the reinforcement. Absorption of moisture by shutters and loss of water by evaporation must be avoided by drenching previously, or, better, by pre-oiling the surfaces concerned.

Curing should allow of suitable protection from the sun's rays by sprinkling water on canvas, kept wet, as appropriate.

Concrete should not be placed at temperatures less than 40°F unless steam curing, or the use of aluminous cement, or other precautions are adopted.

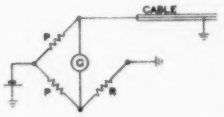
In practice, the requirements of (*a*) can be met by careful gauging in boxes or, better, by weighing materials before mixing. For high-grade work the quantity of moisture present in the aggregates, especially the fine aggregate, must be allowed for by sampling or by permitting only materials known to be dry.

Observance of (*b*) entails careful inspection of materials against the specification and proper storage before use, e.g., the cement must be kept fresh and dry by stacking off the ground in dry conditions.

Correct mixing, placing and curing as earlier specified can only be ensured by observation but, overall, regular slump tests and despatch of sample cubes taken at random and sent for laboratory test are valuable means of ensuring that the quality of the work is maintained at the specified level.

Q. 6. *Describe Mance's test for the localisation of an earth fault on a submarine cable. In what circumstances is the test liable to give misleading results ?*

A. 6. For Mance's test an ordinary Wheatstone bridge is used, connected as shown in the sketch. Secondary cells are used, if available, or alternatively, fresh large dry cells or Leclanché cells as it is necessary for the internal resistance of the battery to be as low as possible. The battery is connected with negative to line.



It is often found that when a faulty wire is first connected to the bridge the measured resistance gradually decreases. The reason for this is that in the electrolytic action that takes place the end of the faulty wire acts as the cathode of the cell and any copper salts that may have been deposited on the wire end, due to the earlier presence of positive potential on the wire, are now removed. Before testing proceeds, the testing current should, therefore, be allowed to flow until the resistance becomes sensibly steady.

Then, the procedure is as follows :—

(1) With equal ratio arms, P_1 P_1, of, say, 100 ohms each the resistance R is adjusted to give a balance at the galvanometer zero. Let the value of R then be R_1.

(2) When the balance is steady the ratio arms are *quickly* changed to values, P_2 P_2, of, say, 1,000 ohms each and the bridge is rebalanced. Let the value of R in this test be R_2.

(3) Tests (1) and (2) are repeated in quick succession until consistent results are obtained.

(4) It may be shown that if x is the line resistance up to and including the fault resistance

$$x = \frac{R_1(1{,}000 + 2B) - R_2(100 + 2B)}{(1{,}000 + R_2) - (100 + R_1)}$$

where B is the internal resistance of the battery. If secondary cells are used B is negligible and may be ignored.

This test is liable to give misleading results (*a*) when there is appreciable resistance in the fault, since the effects of earth currents and polarisation are not then eliminated ; (*b*) when the tests with different values P_1 and P_2 of the ratio arms are not made in quick succession so as to avoid the effects of varying earth potentials which affect the bridge balance.

Q. 7. *Describe briefly what is meant by the term "Effective Transmission," and give the reasons which have led to its adoption as the basis for transmission limits for subscribers' circuits.*

A. 7. The term "Effective Transmission," or as it is now usually called in the B.P.O. the "transmission performance," as applied to a circuit means the effectiveness of the circuit for transmitting or reproducing speech. It takes into account the intelligibility as well as the volume of the received speech, and leads to a truer measure of the effectiveness of a connection than the older Volume Efficiency basis gave. Thus, the newer transmission performance basis takes into account all the controllable factors, viz., the attenuation of the line, feeding-current effect, side-tone, type of telephone instrument and transmission bridge.

The effectiveness of speech transmission is assessed primarily by speech tests (usually articulation tests) of a large number of people. The particular combination of telephone, line and transmission bridge under test may be compared with a standard reference circuit which gives a grade of transmission that is considered to be the minimum acceptable for a subscriber's line.

The reasons for the adoption of the new basis for transmission limits for subscribers' circuits are :—

(*a*) The later telephone instruments of the 232 and 332 types have a better performance than the earlier instruments when assessed on the new basis which does not consider volume only. Thus on a circuit with a small gauge conductor they give a better performance than on one with a large gauge conductor of the same resistance. This enables economies in line plant to be made by using cables of small gauge conductors to the maximum extent.

(*b*) The transmission performance basis takes into account the effects of side-tone and since the later telephone instruments have a better side-tone performance advantage is gained in this respect also.

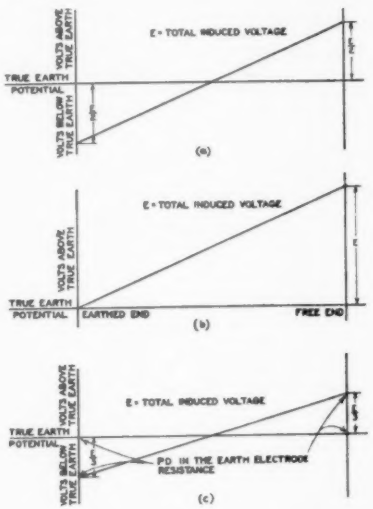
(*c*) Further development of telephone instruments will be in the direction of securing better quality of speech without necessarily increasing its volume and it is clearly essential for the basis of comparison to be closely related to actual service conditions.

Q. 8. *The mutual inductance between a three-phase power line which has no earth wire and a parallel telephone line is 3·9 mH. If the earth fault current is 800 amps. at 50 cycles per sec., calculate the induced voltage. Show by means of diagrams how the voltage to earth will vary along the length of a telephone conductor which is (a) isolated from earth ; (b) earthed at one end ; (c) earthed at both ends. In the last case assume the resistance of each earth electrode to be equal to the resistance of the conductor.*

A. 8. The induced voltage in the telephone line is the product of the earth fault current and the mutual impedance between the power and telephone lines. In the case mentioned the induced voltage would be

$$800 \times 3{\cdot}9 \times 10^{-3} \times 2\pi \times 50 = \underline{980 \text{ volts.}}$$

The voltage distribution along the telephone conductor for the three conditions specified would be as shown in sketches (*a*), (*b*) and (*c*) respectively.



Q. 9. *What do you understand by "fatigue" as applied to cable sheaths ? What are the causes of fatigue effects in aerial cable sheaths, what steps are taken to prevent them developing and what kind of sheath is chosen where resistance to such effects is required ?*

A. 9. A cable sheath that has been subjected to many cycles of stress will fracture at a lower stress than it would have done under a single gradually applied load, and is said to suffer from "fatigue." The cycle of stress may comprise the gradual increase of stress in one direction from zero to a maximum and back again to zero, or the change from a maximum in one direction down to zero and then to a maximum in the opposite direction. When there are complete reversals of stress the resistance to fracture is less than when the variation is one of magnitude in one direction only. The maximum range of stress to which the sheath material can be subjected for an infinite number of reversals is called the fatigue range of the material. In practice it is not possible to test to an infinite number of reversals but it is found that sensibly comparable results are obtained by taking a minimum of ten million reversals.

The main causes of fatigue effects in aerial cables are :—

(*a*) *Temperature variation.*—When a rise in temperature occurs the steel suspension wire expands, its tension is, therefore, reduced and the amount of elastic stretch is reduced. Thus, the extension due directly to temperature increase is offset to some extent by the elastic contraction. The lead-sheathed cable not (generally) having been erected under tension suffers no elastic contraction. This difference coupled with the difference in temperature expansion co-efficients of the two materials, steel and lead, results in the cable sheath having a greater effective expansion than that of the suspension strand and there is excess cable length to be accommodated. This excess length tends to "bow-out" in the unsupported length between adjacent cable rings

and, especially when the temperature rise is large, some of the excess length tends to be pushed to the ends of the span where it accumulates in a large "bow" at the pole. Conversely, when the temperature falls below the temperature at erection, the cable may be under some tension. Variations in the amount of bowing and consequently in the stresses due to bending, give rise to fatigue effects in the lead sheath and fracture eventually occurs.

(*b*) *The action of winds.*—There are two effects possible (i) to produce swaying of the cable and suspension wire, resulting in the application of bending stresses in opposite directions alternately at points where the cable is held or restrained, such as at the pole and to a lesser extent at the cable rings; (ii) to produce chafing and impact of the cable on the cable rings resulting, in time, in "ring cutting" of the cable at the ring positions. The weakened sheath section at these points is then liable to fatigue owing to the effects of cable bowing referred to in (*a*) above, these effects being seen as fine cracks on the inside of the sheath.

(*c*) *Traffic vibration.*—The effect of heavy traffic on an aerial cable erected along the side of a road may be to produce high frequency vibrations in the aerial cable via the poles and suspension wire. Such vibrations would be mostly in a vertical plane and tend to accentuate fatigue effects at the ring positions.

Preventive or remedial measures are in this country seldom necessary except for fatigue effects at cable ring positions. Abroad, where temperature ranges are much greater and more frequent, it is sometimes necessary to relax the normal stringing tension of the suspension wire to reduce the elastic stretch and even to erect the cable under tension as well. To deal with ring cutting and the consequent fatigue effects it is usual either to fit "cradle" rings, i.e. rings with an enlarged seating area for the cable, adjacent to the pole or throughout the span as necessary, or to adopt an alternative method of cable suspension such as by lashing the cable to the suspension wire by means of a lashing machine. Another method is to use a self-supporting type of cable such as the type with a stainless steel sheath.

The other causes of fatigue can generally be met by the use of a suitable alloy for the cable sheath. An alloy containing a small proportion—about 1 per cent.—of antimony has a considerably greater resistance to fatigue than pure lead. This alloy is largely used in B.P.O. practice but elsewhere an alloy containing 0·25 per cent. cadmium and 0·5 per cent. antimony is frequently used as an alternative. To give some increased fatigue resistance as compared with pure lead but not so much as is given by the alloys already mentioned, an alloy containing 0·015 per cent. of tellurium is now frequently used. Such an alloy is suitable for withstanding fatigue due to vibration during transport, particularly by rail.

Q. 10. *Describe* briefly *the various stages of manufacture of trunk type paper core cable. State what tests are made during manufacture of the cable and indicate the method of making each test.* (*Do* not *describe the tests in detail.*)

A. 10. A trunk type paper core cable comprises a given number of paper-insulated copper conductors laid up in quadruple formation in concentric layers with an overall sheathing of lead.

Manufacture. The conductor is rolled and drawn from copper billets and, when the required diameter has been obtained, is coiled and annealed.

The paper which is supplied in rolls is passed over printing rollers for wire identification markings, and is cut to size on rotating cutters.

The conductors forming one quad are cut from one coil and the four insulating papers are similarly taken from one roll to give electrical characteristics of maximum uniformity. Each wire is fed in to the paper-lapping machine through a paper-string container and flat roll of insulating paper via a die to a haul-off wheel and bobbin. The wire is drawn through as the string and paper rotates around it and the die shapes the paper as it passes through. Sometimes the paper string is omitted.

The bobbins of insulated conductors are taken in groups of four and rotated in a cage to form a twisted quad around a central cellulose string. At the same time the quad is cotton-whipped. The length of lay is controlled by the speed of rotation and speed of hauling-off.

In each concentric layer the number of quads increases by six over the proceeding layer, and up to seven cages of drums are mounted in the stranding machine, each cage carrying the appropriate number of drums for one layer. The quads are fed from each cage through holed plates which rotate as the quads are drawn through and so strand them into a cable core. The direction of rotation alternates layer by layer and the speed of rotation controls the length of lay.

Two drums carrying paper insulation are similarly rotated around the completed core which is then coiled on perforated drums and dried in an oven at a temperature of not more than 135 C.

The dried core is then passed through a point and die in a lead press for lead sheathing. The lead is forced by hydraulic pressure between the point and die (which are adjusted to give the correct diameter and thickness) and is water-cooled on leaving the press.

Tests.

Rough tests are sometimes made of resistance unbalance, mutual capacitance and capacitance unbalance prior to drying.

The completed cable is tested for:—

(*a*) Insulation Resistance (wire-to-wire and wire-to-earth) by 500-V battery and galvanometer.

(*b*) Mutual capacitance, by Wien bridge.

(*c*) Conductor resistance and resistance unbalance, by Wheatstone bridge.

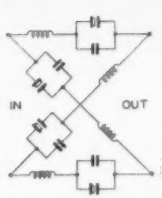
(*d*) Capacitance unbalance, by capacitance bridge.

(*e*) Leakance, by A.C. bridge.

In addition, the copper, paper and lead are tested mechanically and electrically for uniformity, strength and dimensions, and the cable is examined visually for correctness of wire-identification markings.

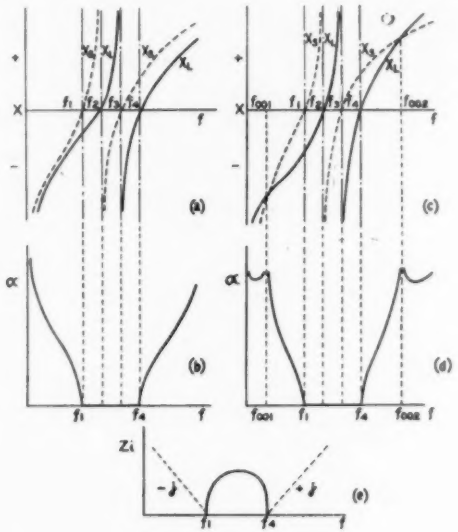
Q. 1. *A crystal filter section is shown in the diagram. Sketch the form of the reactance/frequency characteristics of the series and lattice arms, if the filter is to have a single pass band.*

What would be the attenuation/frequency and image impedance/frequency characteristics of the filter?



A. 1. Sketch (*a*) shows the reactance/frequency characteristics, X_s and X_L, of the series and lattice arms, respectively. As the filter is to have only a single pass band it is necessary to arrange that the anti-resonant frequency, f_2, of the series arms is equal to the lower series resonant frequency of the lattice arms and that the anti-resonant frequency, f_3, of the lattice arms is made equal to the upper series resonant frequency of the series arms.

When the series and lattice arms have reactances of opposite sign there is no attenuation if the section is terminated by its image impedance and if the circuit elements are loss-free; the corresponding attenuation/frequency characteristic is therefore as shown in sketch (*b*).



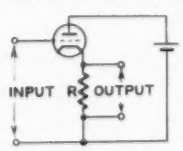
If it is desired that the section has attenuation peaks between zero and f_1 and/or between f_4 and infinity, as well as at zero and infinity, then the series and lattice reactance characteristics may be made to cross as shown, for example, in sketch (*c*). The attenuation/frequency characteristic corresponding to the reactance/frequency characteristic of sketch (*c*) is shown in sketch (*d*).

The form of the image impedance/frequency characteristic of the network is, in each case, as shown in sketch (*e*).

Q. 2. *Explain the operation of a cathode-follower, and indicate the circumstances in which it might be used.*

A cathode-follower employs a triode valve having an A.C. impedance of 10,000 Ω *and an amplification factor of* 30. *Determine its input to output voltage ratio and effective internal impedance if the cathode load resistance is* 200 Ω.

A. 2. The basic circuit of a cathode-follower is shown in the sketch. The load R is in the cathode circuit and hence all of the output voltage is fed back in series opposition to the input voltage, i.e., there is series negative feedback, the feedback ratio β being unity.



If μ and R_a, respectively, are the amplification factor and internal impedance of the valve then the stage gain in the absence of feedback would be

$$\mu' = \mu R/(R_a + R)$$

But the gain is reduced by the presence of negative feedback to $\frac{\mu'}{1 + \mu'\beta}$; as $\beta = 1$ this is

$$\frac{\mu'}{1 + \mu'} = \frac{\mu R/(R_a + R)}{1 + \mu R/(R_a + R)} = \frac{\mu R}{R_a + R(1 + \mu)}$$ which is always less than unity.

Series negative feedback reduces the effective internal impedance of the valve as seen from the load to

$$R_a/(1 + \mu\beta) = R_a/(1 + \mu)$$

A cathode-follower is a useful device if it is desired to couple a high-impedance generator to a low-impedance load.

In the second part of the question it is given that $R_a = 10{,}000$ ohms, $R = 200$ ohms and $\mu = 30$. In this case the output to input voltage ratio is

$$\frac{\mu R}{R_a + R(1 + \mu)} = \frac{30 \cdot 200}{10{,}000 + 200 \cdot 31} = \frac{6{,}000}{10{,}000 + 6{,}200}$$

i.e., the input to output voltage ratio is

$$16{,}200/6{,}000 = \underline{2{\cdot}7}$$

The effective internal impedance of the valve becomes

$$R_a/(1 + \mu) = 10{,}000/31 \text{ ohms} = \underline{322{\cdot}5 \text{ ohms}}.$$

Q. 3. *Discuss the circumstances which lead to the employment of echo-suppressors on trunk circuits. Why are they unnecessary on* 12*-channel and coaxial circuits of less than about* 500 *miles length?*

What are the relative advantages of

(*a*) *a terminal suppressor,*

(*b*) *one-way suppressors at each terminal,*

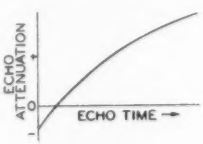
and (*c*) *an intermediate suppressor?*

A. 3. Trunk circuits are operated, almost without exception, on a 4-wire basis and with an overall 2-wire—2-wire loss not greatly in excess of zero. If the 2-wire—2-wire loss of such a circuit is x db. and the balance return losses at the "talker" and "listener" ends are m and n db., respectively, then the theoretical echo attenuations are $(2x + n)$ db. at the talker end and $(3x + n + m)$ db. at the listener end. Clearly, if the balance return losses and the circuit loss are low, then the echo attenuations are low.

The value of balance return loss which can be achieved in practice is limited by the necessity to use a compromise balance designed to give the highest mean return loss with the comparatively wide range of impedance which may be presented at the 2-wire terminals of the circuit. An exceptionally short 2-wire extension may, for example, result in a balance return loss of as little as 4 or 5 db.

A low circuit loss, desirable though it is from all other considerations, necessarily favours a small echo attenuation.

The amount of echo which can be tolerated is a function not only of echo attenuation but also of echo delay. Clearly, if the echo time is zero it appears as sidetone to the talker while to the listener it is an unobserved signal which may add to, or subtract from, the desired signal. As far as talker echo is concerned, a negative echo attenuation is tolerable at very short echo time. As the echo time becomes progressively greater so the tolerable echo attenuation becomes greater, the general form of the characteristic being as shown in the sketch.



Echo-suppressors were first introduced when amplified circuits using heavily loaded cable pairs were brought into use. Heavy loading and amplification were both developed to achieve circuits of low loss and the former resulted in a low transmission velocity. Lengthy circuits were therefore produced, having both a low loss (and, therefore, a low echo attenuation) and a long echo time.

With the introduction of high-velocity circuits (carrier on unloaded pairs) it was possible to accept lower echo attenuation, and echo-suppressors are not used, therefore, on carrier circuits on 12-channel and coaxial systems unless they have a length in excess of about 500 miles.

The relative advantages to be gained by using echo-suppressors at the locations given in the question are as follows:—

1. *Terminal suppressor.*

(*a*) Maintenance is facilitated as the suppressor is at a point where the test level is readily controlled;

(*b*) as both the "go" and "return" elements of the suppressor are at the same point, the action of the device can be

differential, i.e. circuit conditions tending to " close " one sense of transmission can be made to " open " the other.

(*c*) the suppressor may readily be removed if the circuit is required exceptionally to provide two independent " go " and " return " channels, e.g. as a V.F.T. circuit reserve.

The " receive " element of the suppressor must be quick to operate and have a short hangover time.

2. *One-way suppressor at each terminal.*

(*a*) as for 1 (*a*) above ;

(*b*) as for 1 (*c*) above ;

(*c*) can be slow to operate but must have a short hangover time.

Clearly, the suppressors cannot be differentially operated.

3. *Intermediate suppressor.*

(*a*) can be differential ;

(*b*) both the operate and hangover times can be reasonably long.

An intermediate suppressor suffers the following disadvantages :—

(*a*) maintenance difficulties, particularly as it is sited at a point where test levels are not usually under close control.

(*b*) for optimum siting it should be at the electrical (time) centre of a circuit ; this requirement increases the number of repeater stations at which suppressors may be required.

Q. 4. *Explain the principles involved in the assembly of a group of 12 telephone channels in the range 60-108 kc/s, indicating the performance requirements of each unit of equipment involved.*

What are the relative advantages of systems employing (a) direct modulation using crystal filters, and (b) double modulation using non-crystal filters ?

A. 4. The assembly of a group of 12 channels may be accomplished, broadly, in one of two ways :—

(*a*) by the direct modulation of 12 consecutive carrier frequencies and the employment, if necessary, of a subsequent stage or stages of group modulation to locate the channels in the desired group band.

(*b*) by the assembly of a fraction of the channels (a sub-group) within a convenient band of frequencies, additional frequency changing stages being used to form the basic group.

As an example of (*a*), 12 channels may be assembled within the range 60 to 108 kc/s by modulating directly the consecutive carrier frequencies 64, 68, 72 . . 108 kc/s and selecting the lower sidebands. Alternatively, the channels could be formed initially as the upper sidebands of the carriers 12, 16, 20 . . . 56 kc/s and a subsequent group modulation stage, using a carrier of 120 kc/s, used to effect translation to the desired band.

As an example of method (*b*), four sub-groups, each occupying the band 12 to 24 kc/s, could be formed using the carriers 12, 16 and 20 kc/s ; each sub-group would be used to modulate one of the sub-group carriers 84, 96, 108 and 120 kc/s (lower sideband) to form the desired group. As extremes, the " sub-group " may comprise either 1 or 12 channels ; a system in which each channel uses a common first carrier frequency is often known as a " pre-modulation" system.

The assembly of a group may be shown, in a general form, as involving the elements of the sketch. Two stages of frequency

changing are shown ; there may be more or there may be only one.

The first element required is an adjustable attenuator ; the attenuation introduced is such that the test level presented to the frequency-changer has a pre-determined value independent of the loss or gain of any circuit preceding the point of application to the carrier terminal.

The function of the first frequency-changer is to derive the appropriate sidebands, one of which is selected by the filter which follows it. The frequency-changer is required to have a reasonably small conversion loss (say, 7 to 10 db.) of stable value, and not to introduce distortion more than about 40 db. Its input to output characteristic should be close to linear up to, say, 10 db. above test level. If it is not preceeded by some form of voltage limiter, it may also be required to have an input to output characteristic in which the upper part of the linear range merges into a non-linear part with, eventually, a maximum value.

Between the frequency-changer and the channel filter there is usually an attenuator of such magnitude that the indeterminate impedance of the frequency-changer is not presented directly as a filter-closing impedance. Were such an attenuator omitted, the overall attenuation distortion from the channel input to the channel filter output would be much greater than that of the channel filter alone.

It is the function of the channel filter, (*a*) to select the wanted sideband and (*b*) to effect decoupling of the channels of the group or sub-group, so that any one channel absorbs but negligible power from other channels. A typical channel filter required to select the lower sideband of a carrier C kc/s might be required, for example, to introduce attenuation distortion not more than ± 1 db. over the band $C-0{\cdot}3$ to $C-3{\cdot}4$ kc/s and to have an insertion loss not less than 60 db. in excess of the mean pass-band loss over the ranges $C+0{\cdot}6$ kc/s upwards, and $C-4{\cdot}3$ kc/s downwards. It is also desirable that the mean pass-band loss should be low.

At the junction of the channel filters (if more than one or two) it is usual to fit a compensating network to ensure that all of the paralleled filters have a satisfactory terminating impedance. Between the point at which the filters are commoned and the sub-group frequency-changer, there is usually provided an attenuator which is again to afford a satisfactory filter termination.

The sub-group frequency-changer has similar requirements to that of the channel modulator though, particularly if the sub-group is more than an octave wide, the requirements in respect of harmonic production are more stringent.

The requirements of the sub-group filter (which, again, is usually flanked by attenuators) are less stringent than those for the channel filter. Broadly, it is required only that it suppresses adequately all frequencies, other than the wanted sideband, delivered by the sub-group frequency-changer.

The final element in the chain is often a common group amplifier designed to give at its output the desired signal test level. It is required that this amplifier is of stable gain and that its overload and harmonic characteristics are adequate.

The relative advantages of the systems mentioned in the question are as follows :—

(*a*) *Direct modulation system using crystal filters.*

1. Only one stage of frequency-changing is required.
2. The number of elements in the chain is a minimum and hence the physical space required per channel is small.
3. The losses in the transmission path are a minimum and hence the power required for the associated group and channel (receive) amplifiers is comparatively small.
4. A minimum number of valves are required and hence space heating problems are reduced.

(*b*) *Double modulation system using non-crystal filters.*

1. A smaller number of carrier frequencies may be required, e.g. the three channel sub-group system mentioned above requires 7 instead of 12 carrier frequencies.
2. A smaller number of types of filter may be required, e.g. 7 instead of 12 in the above-mentioned system.

Q. 5. *Describe briefly two methods of signalling over carrier telephone circuits and discuss the relative merits of the two arrangements.*

A. 5. Signalling over carrier telephone circuits may be effected by any of the following means :—

(*a*) the transmission of signals, applied at the 2-wire or 4-wire points of a circuit, within the normal voice-frequency band of the channel.

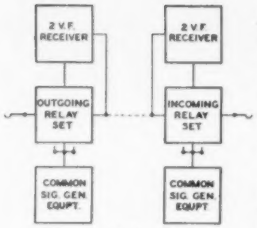
(*b*) the transmission of signals on a parallel channel used to carry, exclusively, the signals of a number of telephone circuits.

(*c*) the transmission of the carrier frequency of the channel (this normally being suppressed except during the signalling process), or of a frequency separated therefrom by the normal channel spacing, or of a frequency close to the carrier and outside the band of the channel filters.

Within the United Kingdom method (*a*) is used exclusively (except for certain experimental installations), the principal systems being known as " 500/20 " and " 2V.F." signalling, but in this answer one system of type (*a*) and one of type (*c*) will be considered.

A 2V.F. System.

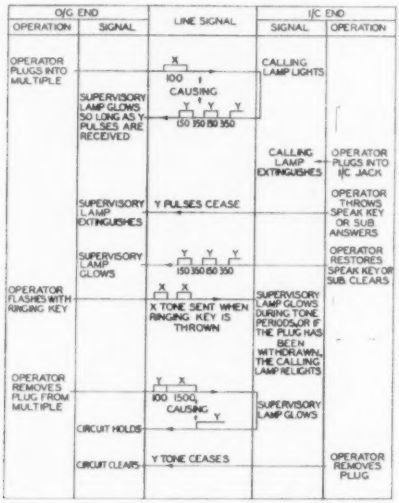
The signalling apparatus is associated with the 2-wire terminals of the circuit and is such as to give manual-to-manual or manual-to-



(*a*)

auto, one-way or both-way signalling. For a manual-to-manual one-way circuit, for example, there is provided a relay set and a signal receiver at each terminal; sketch (*a*) refers.

The signalling frequencies used are 600 c/s and 750 c/s, these being generated by common "tone generating" equipment. By means of the relay sets, signals may be transmitted in either direction, the sequence and duration of the tones being used to define each particular signal. By way of example, sketch (*b*) shows the tone combinations used in manual-to-manual



(*b*)

Note.—The arrows represent the directions of the signals.
The letters represent the frequencies of the signals.
The figures represent the durations (in mS.) of the signals.

one-way working. The X and Y tones are at 750 c/s and 600 c/s respectively.

The relay sets used have a degree of complexity dictated by the wide variety of signal conditions which have to be met.

General requirements for the 2V.F. receiver are that,

(*a*) it must be capable of operating quickly and reliably on the receipt of either of the signal frequencies,

(*b*) operation must be satisfactory over a signal level range of + 10 to − 20 db.,

(*c*) a signal frequency error of ± 0·3 per cent. must be tolerable,

(*d*) it must be immune from operation by trunk line speech, ringing, busy and N.U. tones and telex,

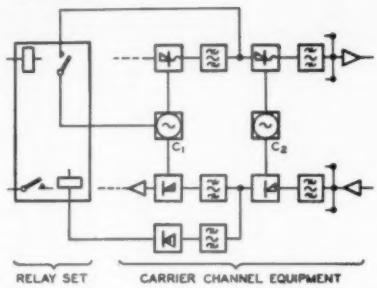
and (*e*) the bridging loss must not exceed 0·25 db.

These requirements are achieved in practice by a receiver incorporating one level-compensating and two tuned relay-operating stages.

A "Transmitted Carrier" System.

A typical system of this kind is illustrated in sketch (*c*). The channel equipment shown is of "double-modulation" type employing carrier frequencies C_1 and C_2. The sketch indicates a signalling relay set appropriate to the four-wire end of a channel but suitable relay sets may also be used at the two-wire point.

The first "send" modulator is of balanced type, the carrier C_1 being effectively suppressed. Any carrier leak which does occur may be further attenuated in the channel filter which follows this modulator. When a signal is to be transmitted, the operation of a relay in the relay set causes a controlled level of carrier C_1 to be applied to the channel at the output of the channel-forming filter.



(*c*)

A received signal frequency C_1 is selected in the receiving section of the channel equipment, by means of a band-pass filter, rectified and caused to operate a relay in the signalling relay set.

Relative merits of the systems.

A merit of the 2V.F. system is that, fundamentally, it is capable of giving six signal conditions (no tone, tone X, tone Y, tones $X + Y$, X followed by Y, and Y followed by X), whereas the transmitted carrier system is capable of only two (tone or no tone). Clearly, a greater range or signalling conditions is possible. (Note. The standard 2V.F. system does not, in practice, use the simultaneous transmission of X and Y tones but does use them consecutively). The system also has the advantage that, however complex the make-up of a circuit, signal conversion is not required at points where the transmission system changes. It also lends itself to tandem signalling when a number of links are connected together. With the transmitted carrier system, signal conversion is necessary at each audio-to-audio junction point with consequent signal distortion and delay.

Merits of the "transmitted carrier" signalling system are as follows. It is inherently simple and, in a homogeneous carrier network, can offer economic advantages. As the signal frequency has no counterpart in the audio channel band (it is either above or below it—in the system illustrated it is equivalent to D.C.), the problem of signal imitation does not arise. In addition, it is possible by careful design to arrange that the signal level is lower for this system than for the 2V.F. method; this results in a reduced demand for line amplifier power handling capacity. Also, signalling is not complicated by the existence of echo-suppressors in circuit.

Q. 6. *State and discuss* three *of the following network theorems*:—
(*a*) *Superposition Theorem*; (*b*) *Compensation Theorem*;
(*c*) *Foster's Reactance Theorem*; (*d*) *Bartlett's Bisection Theorem.*

A. 6. (Author's note. For the sake of completeness the answer deals with all four theorems.)

(*a*) *Superposition Theorem.* "If a network of linear impedances contains more than one generator, the current at any point is the vector sum of the currents that would exist at that point if each generator were considered separately, all others being replaced at the time by impedances equal to their internal impedances."

The theorem can be proved by considering an n-mesh network and applying Kirchhoff's laws though it may, indeed, be argued that, as the impedances concerned (including those of the generators) are linear, it is self evident. It is of great value when analysing complex networks containing a number of independent sources of power.

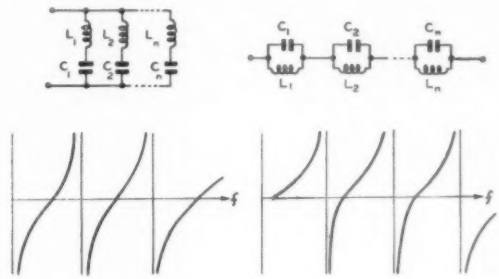
(*b*) *Compensation Theorem.* "Any impedance (linear or non-linear) in an active network can be replaced by a generator of zero internal impedance and of E.M.F. equal to the instantaneous P.D. across the replaced impedance."

The theorem is of particular importance in considering the effect of small changes in the impedances forming a network. To this end, the theorem can be restated as follows:—

"If an impedance δZ is inserted in a branch of a network, the resulting current increment produced at any point in the network is equal to the current that would be produced at that point by a compensating voltage acting in series with the modified branch, whose value is $-I.\delta Z$, where I is the original current that flowed where the impedance was inserted, before the insertion was made."

(*c*) *Foster's Reactance Theorem.* "If two reactance networks have the same resonant and anti-resonant frequencies they can be made to have identical reactances at all frequencies by a proper choice of multiplying factor."

Thus, generalised types of reactance network may be used in design and this is of special importance in the design of lattice filters. Two general types of network are shown in sketch (*a*), together with their reactance characteristics.



(*a*)

Mathematically, the reactance of the generalised network can be expressed as

$$Z = \frac{H}{j\omega} \times \frac{(\omega_1^2 - \omega^2)(\omega_3^2 - \omega^2) \ldots [(\omega_{2n-1})^2 - \omega^2]}{(\omega_2^2 - \omega^2)(\omega_4^2 - \omega^2) \ldots [(\omega_{2n-2})^2 - \omega^2]}$$

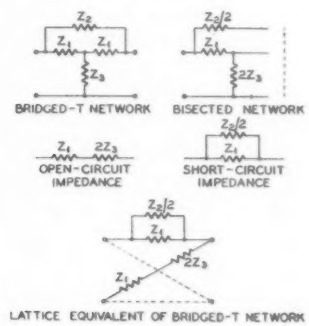
where ω_1, ω_3, ω_{2n-1} are frequencies at which the reactance is zero (resonances); ω_2, $\omega_4 \ldots \omega_{2n-2}$ are frequencies at which the reactance is infinite (anti-resonances); and H is a multiplying factor.

(*d*) *Bartlett's Bisection Theorem.* "If Z_o and γ are, respectively, the characteristic impedance and propagation coefficient of a symmetrical network, then

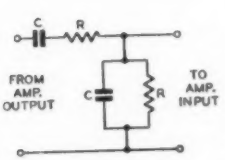
$$Z_{oc} = Z_o \coth \gamma/2$$
$$\text{and } Z_{sc} = Z_o \tanh \gamma/2$$

are the open- and short-circuit impedances of half the network (i.e., the 'bisected' network)."

This theorem enables the lattice equivalent of any symmetrical network to be determined at sight. It can be shown that Z_{oc} and Z_{sc} are the impedances of the lattice and series arms respectively of a lattice network having a characteristic impedance Z_o and propagation coefficient γ; hence, the equivalent lattice structure of a symmetrical network (*not* having lattice elements) is one whose arms are the open- and short-circuit impedances of the bisected network. Sketch (*b*) shows an example of how the theorem is applied to a bridged-T section.



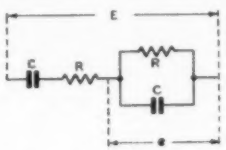
(*b*)



Q. 7. An oscillator consists of a two-stage resistance-capacitance coupled amplifier (phase-shift assumed to be 360°) and a feedback circuit as shown in the sketch.

Derive an expression for the frequency of oscillation and the minimum gain of the amplifier necessary to sustain oscillation.

A. 7. The feedback circuit is re-drawn as in the sketch. Let E and



e be, respectively, the input and output voltages of the network. The impedance of R and C in parallel is $-jR/(\omega CR - j)$

The total impedance across which E is generated is

$$\frac{-j}{\omega C} + R - \frac{jR}{(\omega CR - j)} = \frac{\omega^2 C^2 R^2 - j3\omega CR - 1}{\omega^2 C^2 R - j\omega C}$$

The current produced by E is, therefore,

$$\frac{E\,(\omega^2 C^2 R - j\omega C)}{\omega^2 C^2 R^2 - j3\omega CR - 1}$$

$$\text{Hence, } e = \frac{E\,(\omega^2 C^2 R - j\omega C)}{\omega^2 C^2 R^2 - j3\omega CR - 1} \cdot \frac{(-jR)}{(\omega CR - j)}$$

$$= \frac{E\,(-j\omega CR)}{\omega^2 C^2 R^2 - j3\omega CR - 1}$$

$$\text{i.e. } \frac{E}{e} = \frac{\omega^2 C^2 R^2 - j3\omega CR - 1}{-j\omega CR} = j\omega CR + 3 - \frac{j}{\omega CR}$$

As the feedback voltage e must be in phase with the input voltage E, then

$$\frac{E}{e} = 3 \text{ and, } j\omega CR - \frac{j}{\omega CR} = 0$$

$$\therefore \omega = \frac{1}{CR}$$

Hence, the frequency of oscillation is $1/2\pi CR$ and the minimum gain of the amplifier is $3 = 9{\cdot}54$ db.

Q. 8. Discuss the various forms of noise which occur in wide-band carrier systems and indicate the main source of each type of noise.

A. 8. Noise—as distinct from crosstalk—may be considered under the following headings:—

(*a*) resistance (thermal agitation) noise,
(*b*) valve noise,
(*c*) battery (power supply) noise,
(*d*) externally induced noise, e.g. radio interference,
(*e*) intermodulation noise,
(*f*) inter-channel interference (other than intermodulation noise) caused by inadequate suppression of unwanted products of modulation.

Resistance Noise.—Owing to the random movement of electrons in a conductor there is produced across any resistance an E.M.F. which is proportional to $\sqrt{RfT}$ where T is the absolute temperature in degrees Kelvin, R the resistance and f the bandwidth in cycles per second. Clearly, for a given bandwidth and resistance, a minimum signal-to-noise ratio will occur at a point of minimum signal level. For example, if a line having a characteristic resistance of 140 ohms is terminated by an amplifier (or equaliser) having an input resistance of 140 ohms, then at that point (one of minimum signal level) the net resistance will be 70 ohms; the resistance noise produced at the amplifier input terminals will be that due to 70 ohms. In a channel having a bandwidth of, say, 3,100 c/s, the noise power will be some 133 db. below 1 mW.

In any practical multi-channel carrier system the minimum signal-to-resistance-noise ratio will occur at the input to line amplifiers. Clearly, in a system in which the signal level falls to the same value at the input to each line amplifier, the signal-to-resistance-noise ratio will be degraded progressively; in such a system of n amplifiers, at the input of each of which there is a resistance P.D. of y volts, the net resistance voltage at the input of the final amplifier will be $y\sqrt{n}$ volts.

Valve Noise.—Due to the discrete nature of the emission of electrons from the cathode of a valve, the P.D. produced across the load impedance will have a small fluctuating (noise) component. In amplifier stages subsequent to the first the signal level will normally be so greatly in excess of the noise level as to render the latter negligible; however, the signal level applied to the first stage of a wideband carrier amplifier may be so small as to make the noise voltage significant in comparison. The valve noise produced varies with the type of valve (and, indeed, between valves of the same

type) and with the operating conditions. By judicious selection of valve type and, often, by the use of a step-up input transformer, it is possible to ensure that the signal-to-valve-noise ratio is some 10 db. greater than the signal-to-resistance-noise ratio at the same point.

Battery Noise.—Power supply noise occurs principally in the audio-frequency parts of a carrier channel; in particular, in the receiving channel amplifier; it may also take the form of radio interference as a result of induced voltages in power leads. Generally, however, the low-frequency interference takes the form of "hum" which is due to inadequate suppression of the mains frequency and its harmonics, and to "clicks" due to switching surges caused by relays and like equipment connected to the same supply. Commutator ripple may also be troublesome.

Externally Induced Noise.—This can occur in both the high- and low-frequency elements of a wideband system; if in the former, the interfering source will usually be a radio transmitter while, in the latter, high-amplitude fields from mains-driven apparatus or leads are often the cause. For example, on 12-circuit carrier systems using pair-type cables, radio station interference can occur if the earthing of the sheath is poor, particularly at the low-level end of the cable. On coaxial cable systems the inherent self-screening property of the cable is such that radio station interference does not occur. However, such interference can occur at amplifier stations of both 12- (or 24-) circuit and coaxial cable systems if amplifier screening is inadequate, the most vulnerable point being the input circuit.

Intermodulation Noise.—This is the result of non-linearity in any part of a transmission system carrying more than one channel. Any non-linearity (i.e. departure from a linear voltage/current characteristic) in a path carrying a number of channels will result in the production of multiples of the channel signals, sums and differences of them, and higher orders of sums and differences. Intermodulation effects are usually due to non-linear amplifier characteristics; they are small in a correctly designed amplifier unless the overload point is approached. They will also occur in transformers, especially if overloaded.

Inter-channel Interference (other than intermodulation noise).—This may be due to the production in frequency-changers of signals lying within the frequency band of another channel and which are inadequately suppressed in filters following the frequency-changer. The production of such signals is inevitable in the types of frequency-changer commonly used, and the attenuation/frequency characteristics of filters are designed to give them adequate suppression. When such noise does occur, therefore, it is likely to be due to a fault condition.

Q. 9. Show that, for any passive, symmetrical, four-terminal network, the image transfer coefficient γ is given by

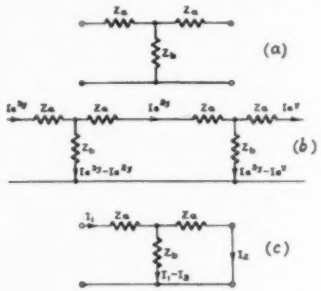
$$\cosh \gamma = \frac{\text{Input current}}{\text{Output current}}$$

when the output terminals are short circuited.

Hence show that, for a T-section having series elements Z_1 and a shunt element Z_2

$$\sinh \frac{\gamma}{2} = \sqrt{\frac{Z_1}{2Z_2}}$$

A. 9. For any passive, symmetrical, four-terminal network there will be an equivalent-T network, i.e. as shown in sketch (*a*).



If two such networks are connected in tandem, the current magnitudes will be as shown in sketch (*b*). If we apply Kirchhoff's laws to the centre mesh, then

$$Ie^{3\gamma}(2Z_a) + (Ie^{3\gamma} - Ie^{\gamma})Z_b - (Ie^{3\gamma} - Ie^{2\gamma})Z_b = 0$$

Dividing by $Ie^{2\gamma}$,

$$2Z_a + Z_b - Z_b e^{-\gamma} - Z_b e^{\gamma} + Z_b = 0.$$

$$2Z_a + 2Z_b = Z_b(e^{\gamma} + e^{-\gamma})$$

$$\text{or, } \frac{e^{\gamma} + e^{-\gamma}}{2} = 1 + \frac{Z_a}{Z_b} = \cosh \gamma$$

The short-circuited network is shown in sketch (*c*).

Clearly, $Z_b(I_1 - I_2) = Z_a I_2$

$$Z_b I_1 = I_2(Z_a + Z_b)$$

$$\frac{I_1}{I_2} = 1 + \frac{Z_a}{Z_b}$$

Hence, $\cosh \gamma = \dfrac{\text{input current}}{\text{output current}}$ when the output terminals are short-circuited.

Now as $\cosh \gamma = 1 + \dfrac{Z_a}{Z_b}$

$$\frac{Z_a}{Z_b} = \cosh \gamma - 1 = \cosh 2\left(\frac{\gamma}{2}\right) - 1 = 2\sinh^2\left(\frac{\gamma}{2}\right)$$

$$\therefore \sinh^2\left(\frac{\gamma}{2}\right) = \frac{Z_a}{2Z_b} \text{ or, } \sinh\frac{\gamma}{2} = \sqrt{\frac{Z_a}{2Z_b}}$$

As, in the question, the series and shunt arms are Z_1 and Z_2 respectively, then, in this case,

$$\underline{\sinh\frac{\gamma}{2} = \sqrt{\frac{Z_1}{2Z_2}}}$$

Q. 10. Describe a transmission measuring set suitable for carrier frequency measurements on one of the following:—

(*a*) *a coaxial-cable system* or

(*b*) *a 12-channel cable-carrier system* or

(*c*) *a 3-channel open wire carrier system.*

A. 10. (Author's note. A transmission measuring set, as used at terminal repeater stations of 12- (or 24-) channel cable-carrier systems, is described; it may be considered as representing, in principle, typical carrier system practice.)

The transmission measuring equipment as a whole may comprise:—

(*a*) a continuously variable audio-frequency oscillator,

(*b*) a carrier-frequency oscillator adjustable to give a number of specific frequencies,

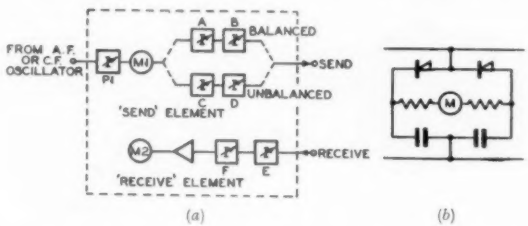
(*c*) a transmission measuring set (T.M.S.), proper, comprising "sending" and "receiving" elements,

(*d*) filters, etc., for measuring harmonic distortion in line amplifiers,

(*e*) a "four-wire" local telephone circuit which may be patched as required to channels under test.

The following description is confined to (*c*) only.

The basic elements of the T.M.S. are illustrated in sketch (*a*).



(*a*) (*b*)

Considering first the "send" element, to the input is connected either an audio-frequency or carrier-frequency oscillator (as appropriate to the test to be undertaken), the output level of which is recorded by meter M1. Potentiometer P1 permits the adjustment of the oscillator voltage, as measured by M1, to a pre-determined value. Prior to the adjustment of P1, a switch is operated to select the impedance condition required at the output of the T.M.S.; it may be 600, 140 or 75 ohms, either balanced or unbalanced with respect to earth. Networks A and C, which are adjustable, determine the level which will exist across the "send" terminals of the set if they are closed by the appropriate impedance; network A is selected if a balanced output is required and network C if the output is to be unbalanced. Adjustable networks B and D determine the impedance to be presented at the "send" terminals of the set. The

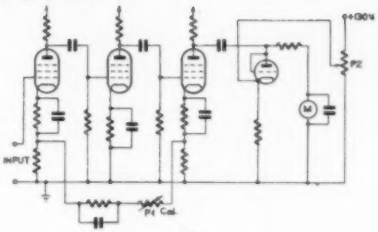
LINE TRANSMISSION II, 1950 (*continued*)

pre-selected levels which may be available at the "send" terminals are 0, -4, -8, -25, -37 and -40 db.

Turning now to the "receive" element, adjustable network E determines the impedance presented by the "receive" terminals; this impedance may be 75, 140 or 600 ohms, either balanced or unbalanced with respect to earth—it may also be a balanced or unbalanced impedance high with respect to the above-mentioned specific values. The high impedance is used when making "through level" measurements, and one of the finite impedances when making measurements of "terminated level." Calibrated attenuator F serves to adjust the level applied to the succeeding fixed-gain amplifier to a value consistent with obtaining a level indication on the decibelmeter M2. Network F is adjustable in fixed steps so calibrated that the measured level is the algebraic sum of the meter reading and a quantity ranging in 10 db. steps from -30 to $+30$ db.

All of the adjustable networks mentioned above are resistive and warrant no further description.

The circuit of meter M1 is illustrated in sketch (*b*); it is of voltage-doubler form. In sketch (*c*) there is shown the circuit of the receiving amplifier and decibelmeter. For clarity, anode decoupling, screen and screen decoupling circuits have not been shown. The amplifier is a three-stage, resistance-capacitance coupled, negative-feedback amplifier and it is followed by a diode



(*c*)

rectifier in whose anode circuit is the decibelmeter (a microammeter). The gain of the amplifier is sensibly constant over the range of frequencies to be measured and may be adjusted by means of potentiometer P1 (Calibrate). Adjustment is effected on applying a known level at the input to the "receive" element of the T.M.S. Residual current in the diode is reduced to a small constant value by means of the bias potentiometer P2.

TELEPHONE EXCHANGE SYSTEMS III, 1950

Q. 1. The impedance of a certain relay at a frequency of 796 c/s is increased from 7,800 ohms $\angle 52°$ to 20,700 ohms $\angle 75°$ by fitting nickel-iron sleeves over the core. Explain this effect and calculate both the inductance and effective resistance of the relay with and without the nickel-iron sleeves.

What effect does the addition of a copper slug have on the impedance of a relay?

A. 1. The increase of impedance at a frequency of 796 c/s from 7,800 ohms $\angle 52°$ to 20,700 ohms $\angle 75°$ is due mainly to an increase in the inductance of the relay at speech frequencies, produced by the fitting of nickel-iron sleeves over the core. In a relay with a soft-iron core without sleeves, the flux due to speech currents links with the solid core and sets up eddy currents which increase in magnitude with increase in frequency. The eddy currents give rise to a magnetic field which, in accordance with Lenz's law, opposes the original field and reduces its intensity, with the result that flux changes in the core are reduced and the inductance of the relay is reduced. The eddy current field is strongest at the centre of the core and weakest at the surface so that the alternating magnetic flux due to speech currents is mainly concentrated near the surface of the core, and it is this flux which, linking with the turns of the winding, determines the inductance of the coil. By making the conditions favourable to the production of the flux, the inductance is increased, and this is effected by fitting nickel-iron sleeves, which are split longitudinally, over the core. The alloy used has a high resistivity and a low hysteresis loss. Its high resistivity, together with the longitudinal splits, minimise eddy currents, and the low hysteresis loss reduces the energy absorbed by the coil, resulting in a substantial increase in inductance.

High permeability of the sleeve material is also desirable, but although the nickel-iron alloy has a high permeability at low magnetising forces, at the high magnetising force due to direct current in the relay coil the permeability is less than that of soft iron.

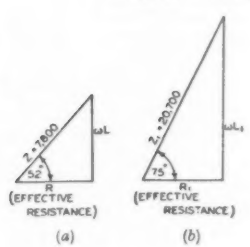
Using given values:—

At frequency $f = 796$ c/s, $\omega = 2\pi f = 5{,}000$

$\sin 52° = \omega L/Z$ (see sketch (*a*))

$L = (Z \sin 52°)/\omega$

$= \underline{1{\cdot}23 \text{ henrys.}}$



(*a*) (*b*)

$\cos 52° = R/Z$

$R = Z \cos 52°$

$= \underline{4{,}803 \text{ ohms.}}$

$\sin 75° = \omega L_1/Z_1$

(see sketch (*b*))

$L_1 = (Z_1 \sin 75°)/\omega$

$= \underline{3{\cdot}998 \text{ henrys.}}$

$\cos 75° = R_1/Z_1$

$R_1 = Z_1 \cos 75°$

$= \underline{5{,}358 \text{ ohms.}}$

The addition of a copper slug to a relay reduces the winding space available so that the number of turns on the coil is reduced, thereby decreasing the inductance and impedance of the relay.

Q. 2. What are the chief effects of (a) inertia, and (b) vibration in the operation and release of a 2-motion selector?

Enumerate the points at which frictional forces have to be overcome during the operation of a 2-motion selector.

A. 2. The ability of one body to take up motion more quickly than another when the same conditions are applied to the bodies is well known. The smaller the time taken by a body to reach a particular speed the smaller is said to be the inertia of that body; conversely, the longer the time taken to reach that speed the greater the inertia is said to be. That is, inertia is the property of resisting motion or movement. For a 2-motion selector, although relay springs and mechanically-operated springsets offer opposition to movement, the more important inertia effects to be overcome are those of the armatures of the magnets and of the wiper carriage. The chief effect of inertia in these parts is to provide opposition to the electro-magnetic forces operating the selector, so that the times of operation of the magnets are increased, and their release times are also increased. The effect of this is to slow down the rate of stepping of the selector. The inertia of the wiper carriage is used to assist the restoration of the wipers in a vertical direction, and in modern selectors, as the inertia of the carriage is reduced to a practical minimum for rapid and efficient operation, a vertical restoring spring is provided.

Vibration of the vertical and rotary armatures may have the effect of increasing and decreasing the armature airgaps so that the magnet operation becomes unreliable, but, in general, the chief effect of vibration of the armatures and the wiper carriage is to reduce the inertia of these parts so that the times of operation of the selector magnets are reduced. The vibration may also assist in causing the armature to release so that the release times of the magnets are reduced. If the vibration is transmitted to the wipers it may become necessary to introduce an artificial delay between the vertical and rotary operations to enable the vibration to subside before the wipers cut into the bank. Vibration increases the mechanical wear on the parts concerned.

During the vertical operation of a modern 2-motion selector frictional forces have to be overcome at the following points:—

Between (*a*) the wiper carriage, carriage restoring spring and shaft.
(*b*) Rotary detent and rotary ratchet.
(*c*) Vertical detent and vertical ratchet.
(*d*) Vertical pawl and vertical ratchet.
(*e*) Vertical pawl and pawl front stop.
(*f*) Cam and comb plate.
(*g*) Vertical marking bank wipers (if fitted) and the bank,
and (*h*) In the vertical armature bearings.

During the rotary operation friction is encountered at the following points.

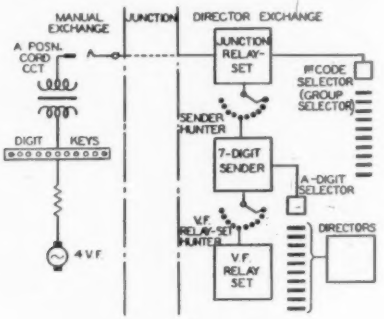
Between (*a*) Rotary disc and comb plate.
(*b*) Wipers and bank contacts.
(*c*) Rotary detent and rotary ratchet.
(*d*) Rotary pawl and rotary ratchet.
(*e*) Rotary pawl and rotary pawl front stop.
(*f*) Cam and rotary off-normal spring-set roller,
and (*g*) In the rotary armature bearings.

As the release of the selector is accomplished by continuing the rotary operation to the 12th rotary step, the points at which frictional forces have to be overcome during this stage are those given in the previous paragraph. During the vertical restoration friction between the rotary detent and the rotary hub has to be overcome; and, during the return rotary release, friction between the wiper carriage and its bearings and finally between the cam and the off-normal spring-set lever operating arm, is encountered.

Q. 3. Describe, with the aid of a block schematic diagram, the operation of setting-up a call on a 4-frequency system of 7-digit keysending from an " A " operator's position into a director system.

Explain in detail how the alternating current pulses are converted into direct current pulses for the purpose of impulsing the automatic equipment.

A. 3. Sketch (*a*) shows a block schematic diagram of the arrangement for 7-digit V.F. keysending by which an " A " operator at a manual exchange sets up calls to director exchanges.



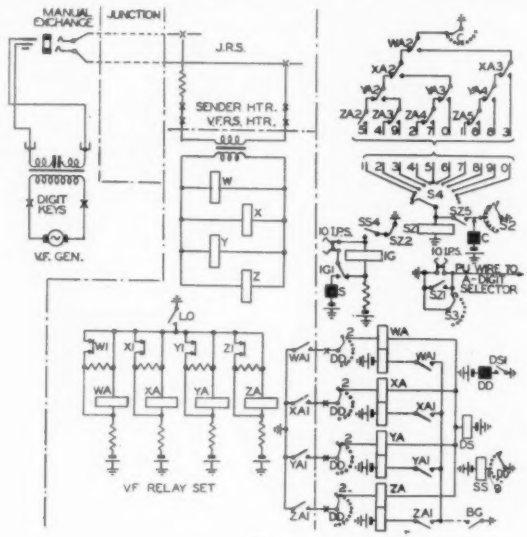
(*a*)

The operation of setting-up a call over this equipment is as follows.

The " A " operator picks up the plug of a calling cord, selects a disengaged junction to the keysending centre, inserts the plug in the selected outgoing junction jack and operates the cord circuit speak key. The insertion of the plug causes the cord circuit supervisory lamp to glow, and seizes the junction relay set (J.R.S.) which is permanently connected to the junction. The sender hunter associated with the J.R.S. hunts for and seizes a free 7-digit sender; then the V.F. relay-set hunter associated with the seized sender searches for, and seizes a free V.F. relay set. When the V.F. relay set is seized two pips of 400 c/s tone are returned to the " A " operator and an answering signal is sent over the junction to dim the calling-cord supervisory lamp, to indicate to the operator that she may commence keying.

The operator depresses the start key, which splits the " A " cord circuit, connects the calling cord to the position transformer, and sends a signal over the junction to the V.F. relay set to release any relays spuriously operated in the sender. She then keys the required exchange code and number. V.F. pulses of the appropriate frequencies, in accordance with the signalling code, are sent over the junction and detected by tuned relays in the V.F. relay set, where they are arranged to operate storage relays in the 7-digit sender. When the 7 digits have been stored in the sender the V.F. relay set is released so that it becomes available for further calls, and the answering signal is disconnected from the junction so that the calling supervisory lamp now glows. The sender transmits the digits as earth-disconnect pulses over a pulse wire to the A-digit selector to which it is connected. The " A " digit steps the A-digit selector which then hunts over the selected level for a free director. The " B," " C," and numerical digits are sent into the director. When the code digits have been received, the director sends out the translation through the A-digit selector, sender and J.R.S. to the 1st and subsequent code selectors. Following this, the numerical digits are sent to the numerical selectors at the required exchange. When the director has completed sending, the director, A-digit selector and sender are released and the connection is switched through the J.R.S. to the code and numerical selectors, and tones are returned to the caller. The calling supervisory lamp continues to glow until the called subscriber answers, when the reversal of the line conditions by the final selector causes the J.R.S. to return the answering signal (battery on the A-wire) to operate the cord circuit supervisory relay and dim the supervisory lamp.

Sketch (*b*) shows in simplified form how the alternating current pulses are converted into direct current pulses for the purpose of impulsing the automatic equipment.



(*b*)

The depression of the digit keys by the operator connects V.F. alternating currents from the V.F. generator to the cord circuit in accordance with the following code :—

Digit key	*Frequency combination (c/s)*	*Relays operated*
1	900	W
2 ABC	750	X
3 DEF	900, 750	WX
4 GHI	600	Y
5 JKL	500	Z
6 MN	900, 500	WZ
7 PRS	750, 500	XZ
8 TUV	900, 600	WY
9 WXY	600, 500	YZ
0	750, 600	XY
START	900, 750, 500	WXZ

The V.F. pulses are sent from the cord circuit, over the junction to the V.F. relay set, where they actuate one or more of the tuned relays, W, X, Y, Z. These relays have a balanced armature connected to a tuned reed, and when the reed is made to vibrate at its resonant frequency it causes a " bobble " contact associated with it to develop high electrical resistance. A sensitive D.C. relay (WA, XA, YA, ZA) is connected across the " bobble " contact of each tuned relay and operates when the contact has a high resistance. The operation of these relief relays connects earth to the W, X, Y or Z wires to operate the appropriate storage relays and relay DS in the sender (in the sketch the "A" digit storage relays, WA, XA, YA and ZA are shown). The storage relays lock over their second coils, and DS1 energises the digit distributor drive magnet. On the release of DS at the end of each digit the digit distributor steps to the next contact connecting the marking wires to the storage relays for the next digit, e.g. " B " digit, WB, XB, YB and ZB. When the sender has completely received all the digits, the digit distributor steps to contact 11 and operates relay SS. SS4

operates relay IG and the sender switch (S) steps at 10 i.p.s. When the sender switch reaches contact 3, a short-circuit is removed from the PU wire impulsing springs and the first impulse is sent over the PU wire. Impulses are sent on each step of the S switch until the S4 wiper encounters the contact marked by earth via the appropriate storage relay contacts. Relay SZ then operates and short-circuits the PU wire impulsing springs to stop the sending of further impulses for that digit. The S switch then homes, and the control switch, C, steps and marks the contacts of the next set of storage relays in preparation for sending the next digit.

Q. 4. Describe the make-up of the signal code used for transmitting each of the signals in a 2-voice frequency system of signalling and dialling.

Suggest briefly, how a single frequency might be employed for transmitting all the necessary operating signals on a signalling and dialling system.

A. 4. The signal code used for transmitting the signals in a 2-voice frequency system of signalling is made up as follows.

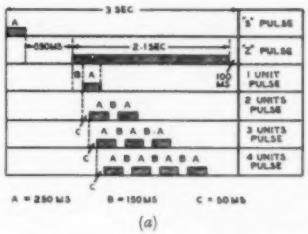
When the operator plugs into the outgoing trunk circuit a 100 mS. pulse of X frequency (750 c/s) is sent as a calling signal from the outgoing relay set over the trunk line to the incoming relay set to prepare it for impulsing and to seize the incoming selector. The supervisory lamp at the outgoing end flickers at this stage until the dial key is thrown. When the operator dials, the " break " periods of the impulses from the dial are converted into 66 mS. pulses of X frequency and passed over the trunk circuit to the incoming equipment where they are re-converted to " break " impulses to step the selectors. When dialling is completed the normal automatic tones are returned to the operator. The ringing and N.U. tones are interrupted for 1 second every 5 seconds, so that any echo-suppressors in circuit may open up for transmission of signals in the reverse direction. When the operator restores the dial key the supervisory lamp glows until the called subscriber answers, then a 200 mS. pulse of Y frequency (600 c/s) is returned to the outgoing end as the answering signal to cause the supervisory lamp to darken. When the called subscriber clears, a series of Y pulses of 140 mS. duration separated by 360 mS. is sent from the incoming relay set to the outgoing end to cause the supervisory lamp to glow. A clearing signal of a 2-second pulse of X frequency followed by a 300 mS. Y pulse is sent from the outgoing end when the operator withdraws the plug from the circuit, to release the selectors and free the trunk circuit. If the called subscriber has not answered when the operator clears, the clearing signal is a 6-second pulse of X frequency followed by the Y pulse, this ensures that the clearing signal is not blocked by echo-suppressors if N.U. tone is returned.

A single frequency might be employed for transmitting the necessary signals on a signalling and dialling system by arranging for discrimination to depend on the duration of the signals and possibly their sequence. One possible scheme would be to use signals in each direction of widely different duration and arrange for the receivers at each end of the circuit to respond effectively only to signals of the appropriate duration. For example, it would be necessary for the receiver at the incoming end to respond to signals of relatively short duration as it has to respond to dialling, so the calling signal could be about 100 mS., but the receiver at the outgoing end could be arranged so that it was ineffective unless the signal was of the order of, say, 500 mS. or 1 second, and an " answering signal " and " called sub. clear " signal of this duration could be employed. A clearing pulse of longer duration than this would be necessary if echo-suppressors are likely to be encountered, and the incoming receiver, which normally responds only to short pulses, could be arranged to respond to a very long pulse. The time response of the receivers might be controlled by relays or uniselectors.

Q. 5. Explain, with reference to diagrams showing the circuit elements concerned, how automatic multi-metering may be effected in a director system.

Indicate, by means of an outline trunking diagram, the routing of calls from one exchange to another in a large director network involving a multi-unit fee when the traffic between the two exchanges is small. Show on your diagram the position of all the transmission bridges used on a call.

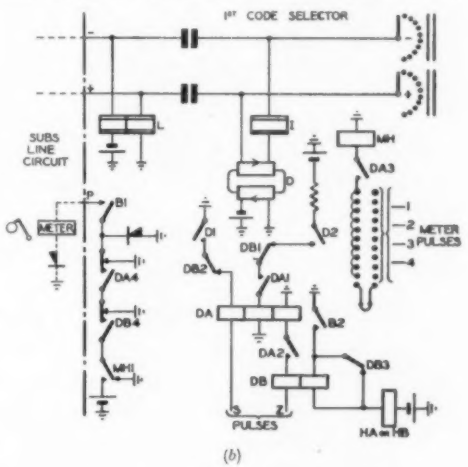
A. 5. Automatic multi-metering may be effected in a director system by a method known as level control of metering. The trunking of the exchange is so arranged that calls necessitating a given number of meter operations (up to 4) are routed through particular code selector levels, and the selectors are equipped with vertical marking banks (V.M.B.), through which the meter pulses are connected to the metering relay. The fee charged is thus determined by the level to which the code selector is stepped and the connection to the V.M.B. For traffic over direct junctions, the metering is controlled simply by the V.M.B. connection of the level over which access to the junctions is obtained, but on junctions to tandem centres where the calls involve more than one class of meter fee the traffic is routed over separate levels for each class of call before access to the tandem route is obtained. The meter pulses are supplied by a meter pulse machine equipped with 1-, 2-, 3- and 4-unit pulse springsets and, as the machine is running continuously, S and Z pulse springsets are provided to connect the metering circuit to the machine at the commencement of a metering cycle and disconnect it at the end of the cycle. The sequence of the meter pulses is shown in sketch (*a*), the shaded portions representing the



(*a*)

periods during which battery is substituted for earth by the cam springs.

Sketch (*b*) shows a circuit element of the arrangements for 1st

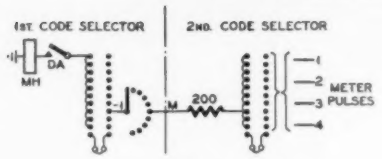


(*b*)

code control of metering and the operation is as follows.

When the called subscriber answers, relay D in the 1st code selector is operated by the reversal of the line potential from the distant final selector. D1 offers relay DA to the S pulse wire and DA operates when the S pulse occurs. DA1 holds DA, and DA2 connects DB, in series with the third coil of DA, to the Z pulse wire. When the Z pulse occurs, DB operates and DA holds, although the other two coils of DA are disconnected by DB1 and DB2. DB3 removes a short-circuit from the locking coil of DB, allowing it to lock in series with the switching relay. During the Z pulse the required number of battery pulses are extended from the meter pulse machine through the V.M.B. and DA3 to pulse relay MH. MH1 extends pulses of battery via DB4, DA4, and the meter wire to operate the calling subscriber's meter. At the termination of the Z pulse, relay DA releases, but DB remains locked throughout the call.

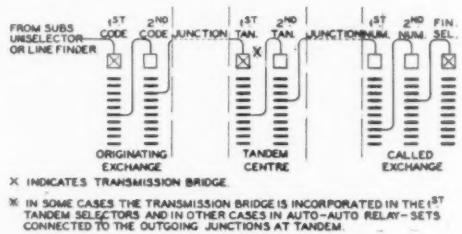
When a 1st code selector level carries traffic of more than one class of fee, the charge is controlled by a V.M.B. fitted to the 2nd code selectors. The arrangement is illustrated in sketch (*c*), which shows level 3 of the 1st code selectors arranged to carry calls of any fee up to 4 units. Level 3 of the 1st code selector V.M.B. is not



(*c*)

wired directly to the meter pulse machine, but is connected to the —1 wiper of the selector, and the —1 bank contacts are wired to the M-wires of 2nd code selectors which are trunked from the even outlets of this level. The P1 bank contacts are earthed so that the availability of the level is reduced from 20 to 10. The levels of the V.M.B. of the 2nd code selectors are commoned on one side and connected to the M-wire, and on the other side are connected to the required meter pulse leads.

The routing of calls from one exchange to another in a large director network involving a multi-unit fee, when the traffic between the two exchanges is small is shown in sketch (*d*)—a tandem


FROM SUBS. UNISELECTOR OR LINE FINDER
1ST CODE
2ND CODE
JUNCTION
1ST TAN.
2ND TAN.
JUNCTION
1ST NUM.
2ND NUM.
FIN. SEL.
ORIGINATING EXCHANGE
TANDEM CENTRE
CALLED EXCHANGE
× INDICATES TRANSMISSION BRIDGE.
* IN SOME CASES THE TRANSMISSION BRIDGE IS INCORPORATED IN THE 1ST TANDEM SELECTORS AND IN OTHER CASES IN AUTO-AUTO RELAY-SETS CONNECTED TO THE OUTGOING JUNCTIONS AT TANDEM.

(*d*)

routing is invariably employed when the volume of traffic is small.

Access to the tandem junction route is obtained via a level of the 2nd code selectors because this group of junctions carries traffic with more than one class of fee.

Q. 6. Enumerate the advantages of demand working for trunk traffic. In what circumstances may it become necessary to introduce delay working, and how would you determine when demand working could be re-introduced ?

A. 6. The advantages of demand working for trunk traffic are given below.

(*a*) Speedier connection of trunk calls.
(*b*) Operating procedure simpler.
(*c*) Saving in operating time.
(*d*) Operator able to deal with more calls than would be possible with delay working so that fewer operators are required.
(*e*) Simpler circulation of tickets.
(*f*) Possibilities of errors are reduced.
(*g*) It is unnecessary to release and recall the subscriber.
(*h*) More satisfactory service to the subscriber.
(*i*) Routing arrangements may be more flexible and alternative routing may be employed.

In demand working when the traffic is heavy, the operator may be unable to find a free circuit on either the primary or alternative routes within a reasonably short time. Normally, she searches for a free circuit for a period of a minute, advising the subscriber after half a minute that she is trying to connect him. At the end of one minute, if she has been unable to obtain a free circuit, she informs the caller that the trunk circuits are engaged and that he will be called later. When these conditions first arise, it is not practicable immediately to resort to delay working. The operator partially completes a call ticket, giving the caller's and the required subscriber's numbers and the booking time, endorses it, and passes it via a pneumatic tube to a distribution position, where the operator passes the ticket to a supervisor. The supervisor assembles such tickets in batches and, in turn, passes them to a " suspended call position " operator, who deals with the uncompleted calls for several routes, endeavouring to set up the connections in order of booking time as circuits become free. When the number of tickets for uncompleted calls over a particular route exceeds a predetermined figure, dependent on the number of circuits in the trunk group, delay working is introduced by the supervisor. The introduction of delay working on a route is indicated to the demand operators by either (*a*) the placing of yellow pegs into the outgoing multiple jacks of the first circuit of the group, or (*b*) the lighting of a red lamp in the free line signalling strip above the jack preceding the first circuit of the group. The supervisor estimates, from the number of waiting calls, and with the aid of a delay calculator, the probable period of the delay, and arrangements are made to post up the delay so that the demand operators are able to advise callers of the expected delay on calls over routes on delay working.

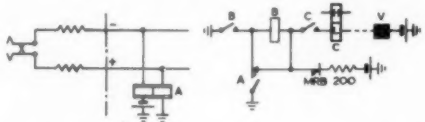
Whilst delay working on a route is in force, the supervisor, from time to time, counts the number of waiting tickets and observes the actual delay by comparing the booking times and connection times on the tickets, so that the probable delay period may be posted up. When the probable delay is reduced to a period of, say, $\frac{1}{2}$ hour, the supervisor keeps a close check on the number of waiting tickets, and if this number shows a continuously steady decrease, consideration is given, after consulting traffic charts, to resuming demand working. If demand working is to be resumed, operators are gradually withdrawn from the delay positions and are used to staff demand positions, and the delay pegs and delay postings are withdrawn. The outstanding waiting call tickets are dealt with at the delay positions.

Q. 7. Explain why the routine tests of a 2-motion selector are sometimes made under conditions which represent, in turn, (a) a long line with high insulation resistance, and (b) a short line with low insulation resistance.

What adjustments to the actual mechanism of the selector, apart from relay adjustments, would tend to have the same effect on the operation of the selector as each of the foregoing conditions ?

A. 7. Routine tests of 2-motion selectors are made under conditions which represent, in turn, (*a*) a long line with high insulation resistance, and (*b*) a short line with low insulation resistance, in order to test the impulsing elements of the selector under extremes of operating conditions.

Under condition (*a*) the current through the impulsing relay is a minimum with the result that its operating lag is a maximum and its release lag a minimum, so that the contacts of the impulsing relay have minimum " make " and maximum " break " periods. As the selector B relay is energised during the make periods of the impulsing relay contacts, and the C relay and magnet circuit completed during the break periods (see sketch), this condition imposes a test to



check that the B relay does not release, and that the selector magnets do release between impulses under these conditions.

Under condition (*b*), the current through the impulsing relay is a maximum during the make periods, and current continues to flow during the break periods by virtue of the low insulation loop. Thus, the operating lag of the impulsing relay is a minimum and its release lag a maximum, and the impulsing relay contacts have minimum break and maximum make periods. Under this condition, the energisation of the B relay is a maximum, and that of the C relay and the selector's magnets a minimum so that a test is imposed to check that the C relay holds and the magnets operate under extreme adverse conditions.

The adjustments to the mechanism of the selector which would tend to have the same effect as the long line, high insulation resistance are :—

(i) low armature restoring spring tensions (armature restoring spring adjusting screws insufficiently extended) ;
(ii) small armature travel due to armature back stop being set too close to the armature in the operated position ;
(iii) light wiper tensions (rotary operation only).

The adjustments which would tend to have the same effect as short line, low insulation resistance conditions are :—

(i) high armature restoring spring tension (armature restoring spring adjusting screw set too far out) ;
(ii) large armature travel—armature back stop set too far back ;
(iii) heavy wiper tensions (rotary operation only).

Q. 8. *The first choice of a full-availability group of trunks is subject to an unguarded interval of* 40 *milliseconds on each call carried by it. Determine the average busy-hour traffic offered to the group if, on an average, just one call is offered during an unguarded interval in ten busy hours, and the average holding time per call is* 2·0 *minutes.*

A. 8. If A = traffic offered, then traffic carried by first choice

$$= \frac{A}{1+A} \text{ T.U.}$$

No. of calls carried by first choice during busy hour

$$= \frac{A}{1+A} \times \frac{60}{2}$$

Unguarded time per busy hour (δt)

$$= \frac{A}{1+A} \times \frac{60}{2} \times \frac{0{\cdot}04}{3600} \text{ hours}$$

Traffic offered during unguarded period $= A.\ \delta t$

No. of calls offered during unguarded period (δt)

$$= A.\delta t \times \frac{60}{2}$$

$$= A\left(\frac{60}{2}\right)\left(\frac{A}{1+A} \times \frac{60}{2} \times \frac{0{\cdot}04}{3600}\right)$$

$$= \frac{A^2}{1+A} \times \frac{1}{100}$$

For 1 call to be offered in 10 hours an average of $\frac{1}{10}$ call must be offered in 1 hour,

hence, $$\frac{1}{10} = \frac{A^2}{1+A} \cdot \frac{1}{100}$$

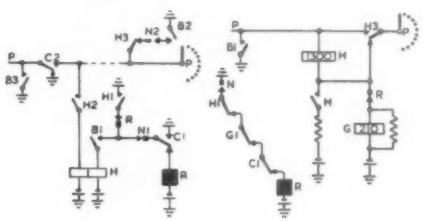
or, $A^2 - 10A - 10 = 0$

and, $A = 10{\cdot}915$ T.U.

Average busy hour traffic = **10·915 T.U.**

Q. 9. *The method known as "cut-drive" is now employed in the design of rotary testing circuits for* 2*-motion selectors. With the aid of simple circuit diagrams, explain clearly why the cut-drive method is more reliable and gives greater speed of operation than the rotary-testing circuit previously employed. State the approximate time, in milliseconds, taken for each of the operations involved in making one rotary step under each method.*

A. 9 Sketch (*a*) shows the cut-drive method now employed in the rotary testing circuits of 2-motion selectors and sketch (*b*) shows the



arrangement previously employed. The modern cut-drive arrangement is more reliable because the circuit arrangement is simpler, in that the rotary magnet has a direct self-interrupted drive circuit which is maintained by a contact of the testing relay H and this relay is held in parallel with the magnet until each step is completed. At this stage relay H tests the P-bank contact and if the outlet is free the disconnected condition of the P-wire allows H to release and cut the rotary magnet drive circuit. The disconnection period of the rotary magnet springs is of the order of 8 mS. and by using H relays with nickel-iron cores, to reduce eddy currents and thus accelerate flux decay, and dispensing with the enlarged pole face, the conditions are met with an adequate margin. The maximum reliability is obtained by this simple self-drive circuit, which is made possible by the positive toggle action of the R magnet springs which are arranged to open on the completion of the R magnet operation and close again on the restoration of the armature. Maximum stepping speed is obtained by this arrangement as the only factors determining the speed are the times of operation and release of the R magnet.

In the previous arrangement, shown in sketch (*b*), the reliability is reduced as the rotary stepping is dependent upon the satisfactory operation of the R springs, relay G and the G1 contact at each step. The necessity to operate and release relay G for each step increases the stepping time and reduces the hunting speed.

The approximate times, in milliseconds, for each operation involved in making one rotary step are,

(*a*) in the modern cut-drive arrangement,
- (i) operation of R magnet, 20 mS.
- (ii) release of R magnet, 7 mS.

and (*b*) with the previous arrangement,
- (i) operation of R magnet, 27 mS.
- (ii) operation of relay G, 10 mS.
- (iii) release of R magnet, 6mS.
- (iv) release of relay G, 10 mS.

Q. 10. *During a* 90*-second period of a busy-hour, calls are allotted to the two markers serving a C.C.I. position at the times shown below. Making the following assumptions,*

(*i*) *both markers and the display are free when the first call (at* 73 *seconds past the hour) arrives,*

(*ii*) *on each call a marker is engaged for a period of* 2 *seconds during circuit operations of decoding, etc.*

(*iii*) *the display on each call lasts for* 5 *seconds,*

determine, by means of an artificial traffic record with the 10 *calls given below,—*

(*a*) *the proportion of calls held in delay waiting for the display to become free,*

(*b*) *the average delay in seconds of the calls delayed,*

(*c*) *the proportion of time two markers are simultaneously engaged,*

(*d*) *the proportion of time only one marker is engaged.*

Calls allotted to the markers at the following times past the hour, 73, 98, 110, 111, 117, 131, 137, 140, 146, *and* 163 *seconds.*

Compare (*c*) *and* (*d*) *with the proportions derived from the Erlang lost-call formula, and suggest reasons for the differences.*

A. 10. Tabulating the given data,

Call Allotted to Marker at (secs.)	*Marker Released*	*Display Released*	*No. of calls Delayed*	*Delay Period*	*Time 2 markers Engaged*	*Time 1 marker Engaged*
73	75	80	—	—	—	2
98	100	105	—	—	—	2
110	112	117	—	—	1	1
111	117	122	1	4	—	5
117	122	127	1	3	—	5
131	133	138	—	—	—	2
137	139	144	—	—	—	2
140	144	149	1	2	—	4
146	149	154	1	1	—	3
163	165	170	—	—	—	2
		Totals	4	10	1	28

(*a*) Proportion of calls held in delay waiting for display to become free $= 4/10 = \underline{0{\cdot}4}$

(*b*) Average delay in seconds of calls delayed $= 10/4 = \underline{2{\cdot}5}$ secs.

(*c*) Proportion of time two markers are simultaneously engaged

$$= \frac{1}{(163-73)} = \frac{1}{90} = \underline{0{\cdot}01}$$

(*d*) Proportion of time only one marker is engaged $= 28/90 = \underline{0{\cdot}31}$

The traffic carried by the markers is that due to the time a single marker is engaged, i.e. 1 call for 28 seconds, plus that due to the time that 2 markers are engaged, i.e. 2 calls for 1 second. Thus, the total marker traffic is $28 + 2 = 30$ seconds out of 90 seconds—in other words, the marker traffic $= 30/90 = 1/3$ T.U.

The proportion of time 2 markers are engaged is given, theoretically, by

$$\frac{A^2/2!}{1 + A + A^2/2!}$$

which equals 0·04 (when $A = \frac{1}{3}$)

Proportion of time 1 marker engaged $= \dfrac{A/1!}{1 + A + A^2/2!} = 0{\cdot}24$

The proportions derived from the Erlang formula differ from those obtained from the artificial traffic record because :

(1) The Erlang formula applies strictly only to the case where calls are lost and not delayed, i.e. if a call cannot get into display when the call arrives the Erlang equation assumes that the call would be lost and not delayed. Hence, the Erlang formula is not strictly applicable to these conditions.

(2) The artificial record itself covers such a small sample that it would be very unlikely for the results to agree with any theory.

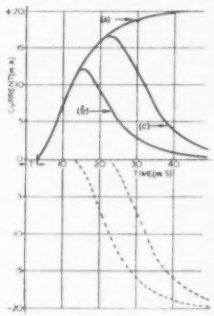
TELEGRAPHY II, 1950

Q. 1. *State what you understand by the term* arrival curve, *and explain upon what factors the shape of the curve depends. Show how the shape of the received signals on a telegraph line may be predicted from a knowledge of the arrival curve. Use the following example to illustrate your answer.*

Plot graphs of the received current for signals of 10 *milliseconds and* 20 *milliseconds duration sent on a line for which the growth of the received current when a battery is applied to the sending end is as follows* :—

Time (*mS.*) ..	0	5	10	15	20	25	30	35	40
Current (*mA*) ..	0	1·5	7	13	16	18	19	19·5	20

A. 1. An arrival curve is the graph which results from plotting against time, the current received at the end of a telegraph transmission line when a steady voltage is suddenly applied at the sending end, the line being previously in a state of rest. Such a curve, (*a*) in the sketch, has been drawn from the data provided.



A telegraph transmission line is a ladder network consisting of distributed elements mainly of series resistance R and shunt capacitance C. When a voltage V is suddenly applied at the sending end the charging current I flowing into the first capacitance element is determined by the law :—

$$I = \frac{V}{R} e^{-t/CR}$$

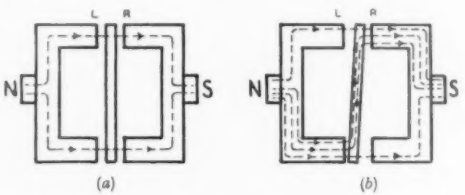
As a result the full voltage available to the second element or section of the transmission line is delayed until the first capacitance element is, sensibly, fully charged. Each element of line capacitance must be charged successively before an appreciable signal voltage appears at the receiving end. The time, measured from the instant of applying the sending voltage, during which no measurable current is discerned at the receiving end is known as the "silent interval"—T in the sketch—and it is the propagation time of the transmission line. The time required for the current to build up to a given percentage of the final value is proportional to the product CR.

The shape of the received signals on a telegraph line may be predicted from a knowledge of the shape of the arrival curve by graphical application of the method of superposition. For each application of the sending voltage the arrival curve may be drawn, commencing at the appropriate instant of time. Each removal of the sending voltage may be regarded as due to the application of an equal but opposing voltage at the sending end and the reversed arrival curve is drawn accordingly. At any instant of time the received current is determined from the summation of the instantaneous values of currents on the arrival curves. The shape of the current curves for signals of 10 mS. and 20 mS. duration is shown in graphs (*b*) and (*c*) respectively.

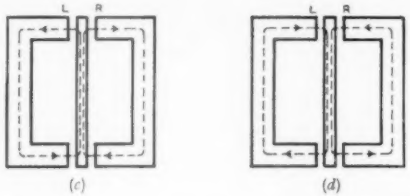
Q. 2. *Discuss the theory of the polarised telegraph relay by reference to sketches showing the distribution of the magnetic flux due to the permanent magnet and the operating current.*

How is (*a*) *the sensitivity*, (*b*) *the contact pressure for a given operating current, related to the value of the flux due to the permanent magnet ?*

A. 2. The sketches show the distribution of flux in the polarised



telegraph relay under various conditions. NS is the permanent magnet fitted with two U-shaped pole-pieces enclosing the armature which is pivoted at its centre. The winding (not shown) encloses the armature except for its ends.



Sketch (*a*) shows the two parallel paths taken by the flux from the permanent magnet, NS, if the armature is precisely midway in the air gaps : the two ends of the armature are at points of equal magnetic potential and there is no flux in the length of the armature.

Sketch (*b*) shows the flux from the permanent magnet if the armature is displaced from its unstable central position. The inequality of the air gaps results in unequal reluctances in the pairs of air gaps and there is now a small flux in the armature because its two ends are no longer situated at points of equal magnetic potential.

Sketches (*c*) and (*d*) show the flux due to the electromagnet alone, produced by the current flowing in the relay windings in one direction or the other.

With the current in a direction such that it produces the flux shown at (*c*), the permanent magnet flux in the right-hand air gap R is reinforced to hold the armature in the position shown at (*b*). If the current is reversed (sketch (*d*)) and is of sufficient magnitude, the magnetomotive force produced in the armature by the current in the windings reverses the flux in the armature, weakens the flux in gap R and strengthens the flux in gap L, causing the armature to move to the opposite position from that shown at (*b*).

As soon as the armature commences its travel across the air gap, the effect of the permanent magnet flux in the armature decreases until, at the mid-point, its effect is zero (sketch (*a*)). At this instant, the armature motion is due to its own momentum, together with the pull due to the net preponderance of flux in the gap L over the gap R (and of course to corresponding flux conditions in the lower air gaps). Immediately the centre point is passed the effect of the permanent flux in the armature is reversed, its intensity increasing as the motion proceeds and the air gap shortens. This flux assists the electromagnetic flux in bringing the armature over smartly and ensuring a firm contact pressure. In this respect its operation may be contrasted with that of a non-polarised relay in which the controlling force always opposes the operating force. In the polarised relay the electromagnetic flux need be only sufficient to reverse the direction of flux in the armature and after its initial movement the armature travel is actually assisted by the permanent flux : this is one factor which gives the relay its high order of sensitivity.

(*a*) The operating current must produce sufficient flux to overcome the flux which is present in the armature due to the permanent magnet. The sensitivity of the relay is therefore inversely proportional to the strength of the magnet. If the permanent flux is too great the sensitivity of the relay will be reduced. If the flux is too small, although the minimum operating current will be low, the relay will be unstable in operation.

(*b*) For a given operating current the contact pressure will be greater, the greater the flux due to the permanent magnet.

Assuming the relay armature to be held operated to one side by current flowing through the winding then, if

Φ_M is the flux passing along the armature due to the permanent magnet,

and Φ_O is the flux in the armature due to the operating current, the force exerted on the armature, and therefore the contact pressure, will be approximately proportional to

$$\left(\Phi_M + \frac{\Phi_O}{2}\right)^2 - \left(\frac{\Phi_O}{2}\right)^2 = \Phi_M{}^2 + \Phi_M \Phi_O$$

(*Note.*—The permanent magnet flux which passes across the gaps between the yokes without traversing the length of the armature has a negligible effect).

Since Φ_O must at least be slightly greater than Φ_M, or the relay would not move from the unoperated to the operated position, it will be seen that the contact pressure is proportional to the square of the permanent magnet flux plus a further substantial factor dependent on the flux due to the operating current. This accounts for the positiveness of action which can be obtained from small operating currents with a polarised relay, as compared with a non-polarised relay.

Q 3. *Describe with the aid of sketches the construction of the receiving cam sleeve of a teleprinter. Enumerate in correct sequence the functions it performs.*

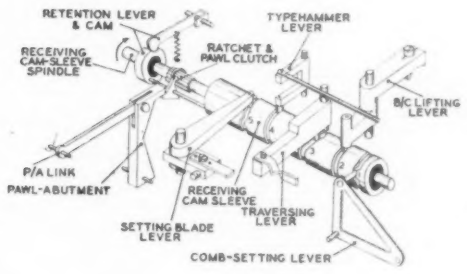
Calculate the margin of a teleprinter having the following characteristics :—

(*i*) *The finger setting blade must remain in contact with the finger setting pin during at least* 6° *rotation of the cam sleeve to set the selecting fingers reliably.*

(*ii*) *The clutch has* 60 *teeth.*

(*iii*) *The cam sleeve completes one revolution in the time of* 6·5 *signal elements.*

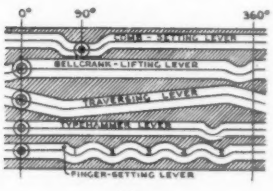
A. 3. The receiving cam sleeve of a teleprinter (sketch (*a*)) consists of a steel cylinder on the surface of which are cut five grooves : the shapes of these grooves or tracks determine the movements of certain levers which, riding on rollers, move in the tracks. These levers operate with reciprocating movements and they are employed in connection with the various operations concerned in the selection and printing of the required characters and with the movements of the paper carriage mechanism.



(*a*)

The cam sleeve is supported at each end upon bearings and is driven by means of a clutch consisting of a ratchet and pawl. By means of the pawl abutment the pawl is prevented from engaging with the ratchet while the electromagnet armature is in the marking position. When a space (start) signal is received, the pawl abutment link removes the pawl abutment from the path of the pawl which is forced by its spring into engagement with the ratchet wheel : the receiving cam sleeve now commences to rotate, being driven from the motor shaft through gearing. The speed of the cam sleeve is such that it makes one complete revolution during the reception of each signal combination.

During the stop (mark) signal the pawl abutment is reset and withdraws the pawl from the ratchet so bringing the cam sleeve to rest. During the receipt of code signal elements the pawl is rotating clear of the pawl abutment. The retention lever holds the cam sleeve stationary in the rest position, and ensures that the pawl is drawn clear of the ratchet wheel.



(*b*)

The five cam tracks are shown in developed form in sketch (*b*). The comb-setting lever is positioned to operate 90° ahead of the other levers. The functions performed by the cam sleeve are enumerated below in their relation to the signal elements.

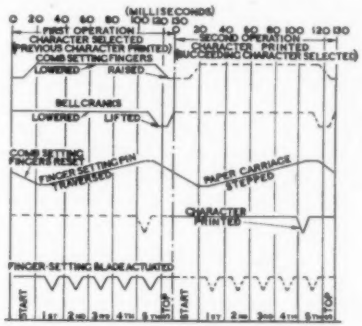
Start Element. The comb-setting fingers are lowered and reset to their normal position. The finger-setting pin moves from its rest position (opposite the third comb-setting finger) to a position opposite the first finger.

Code Elements 1-5. The finger-setting blade lever makes five oscillations so that at the mid-point of each signal it strikes the finger-setting pin (mark element) to actuate the comb-setting finger. The traversing lever travels uniformly so that the finger-setting pin moves past each comb-setting finger during the relative signal period. At the same time the paper-carriage operating lever is given a uniform motion to feed the paper to a fresh space for printed characters.

During the fifth element period the type-hammer lever is operated to print the character previously received, the paper-carriage remaining stationary instantaneously for this purpose.

Stop Element. All bell-cranks are lifted to enable the previous character, now printed, to be released and the freshly selected character to be stored in the combination head. To effect the latter, the comb-setting fingers are raised while the bell-cranks are lifted free of the receiving combs. The bellcranks are restored during this period to enable the newly selected combination to be stored, the comb-setting fingers remaining in the raised position. These two operations actually commence during the latter portion of the fifth code element. The finger-setting pin is restored to its rest position, opposite the third comb-setting finger.

A timing diagram of these events is given in sketch (*c*), the character selected during one cycle being printed during the subsequent cycle.



(*c*)

Since one complete revolution of the cam sleeve occupies the time of 6·5 signal elements and the clutch has 60 teeth, the variation in pick-up time expressed as a percentage of the time of a unit signal is

$$\frac{6{\cdot}5}{60} \times 100 = 10{\cdot}8 \text{ per cent. or } \pm 5{\cdot}4 \text{ per cent.}$$

The angular displacement of the cam sleeve during one unit is

$$\frac{360° \times 2}{13} = 55{\cdot}4°$$

If the contact between the blade and pin must be 6° minimum the margin on this account is

$$\frac{55{\cdot}4° - 6°}{55{\cdot}4°} \times 100 = 89 \text{ per cent. or } \pm 44{\cdot}5 \text{ per cent.}$$

This theoretical margin may be reduced by the variation in pick-up time so that the true calculated margin is (44·5—5·4)

$$= \pm \underline{39 \text{ per cent.}}$$

Q. 4. *Discuss the factors controlling the following points in the design and operation of a multi-channel voice-frequency telegraph system :—*

(*i*) *The band-width of the filters.*

(*ii*) *The number of channels.*

(*iii*) *The choice of the channel frequencies.*

(*iv*) *The power transmitted per channel.*

(*v*) *The use of "tone-on" as the rest condition and not "tone-off."*

A. 4. (*i*) *The bandwidth of the filters.* When a carrier current is modulated by one at signal frequency s the modulated current covers a bandwidth of $\pm s$ about the carrier frequency, a total of $2s$.

With D.C. telegraph signals the signalling frequency is equal to one-half of the speed in bauds and the bandwidth (in cycles/second) after modulation is equal to the signalling frequency in bauds.

When square-topped modulated signals are passed through a band-pass filter the build-up of the signal envelope is delayed by $t \triangleq 1/(f_2 - f_1)$ secs., where f_1 and f_2 cycles per second are the approximate cut-off frequencies. Signals having a duration less than t seconds will not be transmitted properly, and the limiting telegraph speed in bauds is $N = 1/t = (f_2 - f_1)$, i.e. the telegraph speed in bauds is proportional to the bandwidth.

The filter should offer little attenuation over the bandwidth corresponding to the modulated signal. To allow for the attenuation/frequency characteristic of the filter, the nominal bandwidth of the filter would need to be somewhat greater than the effective bandwidth.

(*ii*) *The number of channels.* For a given bandwidth the maximum number of channels which can be operated is dependent upon the effective transmission band of the line. The line attenuation must be equalised over the transmission band so that the performance of all channels will be identical. The maximum number of channels operating simultaneously must be related to the power required to operate a channel satisfactorily and to the maximum power which the repeaters can handle without overloading.

If the system is to be operated over a two-wire line, the number of channels is reduced owing to the need for using different frequencies for either direction of transmission.

(*iii*) *The choice of the channel frequencies.* Non-linearity in the transmission equipment distorts the waveform, producing harmonics $2f$, $3f$, etc., of a fundamental frequency f.

The simultaneous application of power at two or more carrier frequencies f_1 and f_2, etc., is liable to result in cross-modulation producing a series of sum and difference frequencies between fundamentals and harmonics. Excluding those summation frequencies which lie outside the frequency range of the system the first-order products of cross modulation, $2f_1$, $2f_2$, $(f_1 + f_2)$ and $(f_1 - f_2)$ are those having the greatest amplitude and liable to cause undesirable interference.

By choosing the odd multiples of a basic frequency for use as the channel frequencies, all even harmonics and also all sum and difference frequencies fall midway between the channel frequencies, i.e. at those points where the channel filters exercise their maximum attenuation.

(*iv*) *The power transmitted per channel.* The determination of power to be transmitted by each channel is limited on the one hand by the signal/noise ratio in conjunction with the line attenuation, and on the other hand by the maximum power which can be carried by the repeaters when they amplify the signals of all channels simultaneously. If the repeater valve is overloaded by the peak power of all channels, cross-modulation interference and distortion will occur.

(*v*) *The use of "tone-on" as the rest condition and not "tone off."* The employment of a "tone-off" rest condition to denote an idle or free circuit is of considerable advantage in the design of supervisory signalling circuits for switched telegraph systems.

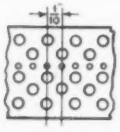
From a transmission aspect the choice of "tone-on" or "tone-off" for the rest condition is closely associated with the question of automatic gain control. With the use of an amplitude-modulated transmission system any change in the amplitude of received signals is equivalent to the introduction of bias since the transmission system is essentially single-current. To compensate for the normal fluctuations in line level, A.G.C. is introduced into the receiving amplifier-detector equipment. This A.G.C. is effective only when the level of the incoming signal is above a predetermined lower limit and for tone-on working it has a time-constant sufficient to maintain it in operation during the longest period of no-tone (space) signal likely to be experienced during signalling.

On the other hand, if "tone-off" is used during the rest condition the receiving amplifier-detector returns to its maximum sensitivity during periods of no signalling: upon the arrival of the first tone signal following a long period of no-tone the maximum amplification is afforded and the resulting grid current is sufficient to suppress the amplifier-detector for a period until the grid capacitor discharges into its shunting resistor. This effect, known as "lock-out" can be overcome by the provision of an additional resistance-capacitance element with a relatively low time constant to decouple the amplifier and rectifier grids and prevent the shut-down condition.

Q. 5. Give a description of a transmitter suitable for the automatic transmission of teleprinter signals.

If such a transmitter is adjusted to transmit at 60 bauds, calculate the rate (in feet per minute) at which the tape runs through the transmitter. (The perforated tape has 10 centre holes to the inch.)

A. 5. The automatic transmission of teleprinter signals is achieved by passing a perforated tape through an automatic transmitter. The tape is perforated with holes in accordance with the five-unit code (sketch (*a*)), a hole in the tape corresponding with a mark signal element. A train of smaller holes spaced at $\frac{1}{10}$ in. centres is also provided in the tape for the purpose of feeding it through the transmitter.

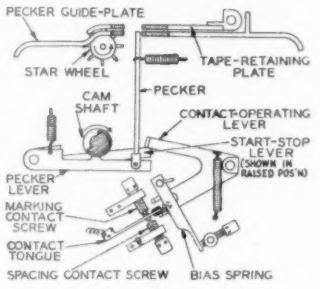


(*a*)

The transmitter is driven by a governed D.C. shunt motor, the governor being similar to that used on the teleprinter motor. The motor drives a transmitting cam sleeve through a 6·4 : 1 reduction gear, the cam sleeve rotating at 400 r.p.m. for a transmission speed of 50 bauds. Geared to the camshaft is a star wheel whose teeth engage the feed holes in the paper tape, the gearing being such that the paper is advanced by the distance between two adjacent feed holes for each revolution of the cam sleeve.

The general arrangement of the transmitting head is shown in sketch (*b*).

The cam sleeve has six tracks, five corresponding to the five code elements and the sixth to the start and stop elements. Against each track a pecker lever is held by a spring, each of the five code levers supporting a vertical pecker rod: the tips of these rods pass through slots in the tape platform. The ends of the six pecker levers control a single contact-operating lever which determines the position of the transmitter tongue with relation to the space and mark contacts.



(*b*)

When the transmitter is operating the hump on the start-stop pecker lever rides out of the recess on the cam track, allowing the contact-operating lever, under the influence of its spring, to move the tongue to the space contact. The recesses in the five remaining tracks then pass, in turn, over the humps on the relative pecker levers. If there is a corresponding hole in the tape the pecker will be free to rise and the hump on the lever will ride into the recess in the cam track, throwing the contact-operating lever upwards and causing the tongue to move to the mark contact. In the absence of a hole in the tape the pecker rod is restrained by the paper from rising, the hump cannot ride into the recess in the cam track and the contact-operating lever, influenced only by its restoring spring, holds the tongue against the space contact.

The tongue is held in position by a jockey roller tensioned against its tip to produce short transit times. Since the paper is moving continuously the peckers must be free to move forward whenever they enter a hole in the tape. For this reason the pecker guide is slotted and the peckers are held against the back ends of the slots by light springs.

To prevent the paper tape from being torn should it become taut, it is taken under a roller mounted upon a pivoted lever. A ratchet and pawl clutch of the type used in the teleprinter is provided on the driving spindle. When the pivoted lever is drawn upwards by the paper becoming taut a pawl abutment is placed in the path of the pawls of the clutch: this withdraws the pawls from the ratchet wheel and the cam sleeve and star wheel are brought to rest. A retention lever is provided to locate the cam sleeve in the correct stopping position, i.e., when the start-stop cam lever is in the stop position. This ensures that the character in course of transmission when the tape tightens is completely sent out and also that when the tape control lever is again moved to recommence transmission the subsequent character-combination sent is not mutilated.

At 60 bauds, using a signalling code of 7·5 units, the time of one signal element is 1/60 second and the time for transmission of one character combination is 7·5/60 secs.: this occurs during the movement of the tape to the extent of $\frac{1}{10}$ in. Hence, the rate at which the tape runs through the transmitter (=distance/time)

$$= \frac{60}{10 \times 12 \times 7{\cdot}5} = \frac{1}{15} \text{ ft./sec.} = \underline{4 \text{ ft./min.}}$$

Q. 6. Describe a typical power installation suitable for a large telegraph office. Explain the means adopted for avoiding variations in the voltage of the supplies and for preventing a breakdown of service under mains failure conditions.

A. 6. At a large telegraph office power is required to drive the teleprinter motors and provide the line signalling currents: in addition, if a switchboard installation is in use, power supplies are required to operate the signalling lamps and relay switching equipment.

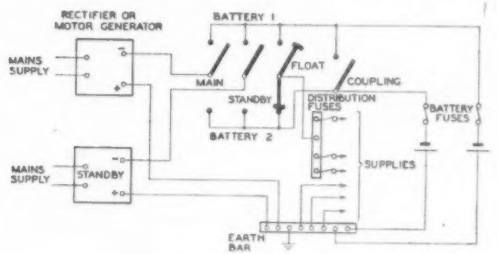
A double current supply at ± 80 V is used for signalling: the teleprinter motors are driven at 160 V, obtained from the outer terminals of the ± 80 V signalling battery. This same supply is used for energising relays in switchboard equipment; for supervisory lamps a 6 V supply is provided.

If the multi-channel voice-frequency equipment is accommodated in the same telegraph office, low tension (L.T.) and high-tension (H.T.) supplies are required for the cathodes and anodes of the valve equipment.

In order to prevent a breakdown of service under mains failure conditions, floating battery systems are used in which the mains supply, the battery and the load are, in effect, connected in parallel. Should the mains supply fail the load is supplied from the battery which is given sufficient capacity to maintain the supply for 24 hours, with some reduction in the 160 V load obtained by switching off a suitable proportion of the teleprinter motors. A divided battery system is normally adopted: in this system the total capacity required is divided equally between two batteries. For normal working one battery is floating on load and the other is on charge, the batteries being changed over at weekly intervals. In the event of mains failure both batteries are paralleled to share the load. When the mains supply is restored one battery is recharged; when charged this battery is substituted for the battery on load which is then recharged.

If A.C. mains supplies are available rectifier units are used to provide outputs at ± 80 V, 130 V (H.T.) and 21·5 V (L.T.). If the mains are of D.C. supply, motor-generator sets are used to supply these outputs: motor generators may also be used with the A.C. mains if the load requirements exceed an economical figure for rectifiers. In either case, rectifiers or machines, duplicate sets are installed to provide against stoppage, were failure to occur in the working rectifier or generator, and also to make available a separate source of supply for battery charging, particularly necessary after a mains failure.

The general layout of this equipment is illustrated in sketch (*a*)

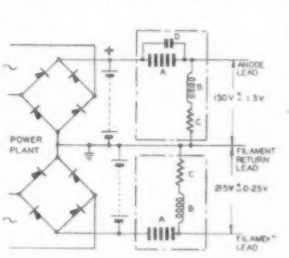


(*a*)

which indicates the switching system for floating or charging either half of the battery or for combining both parts under mains failure conditions. The switch used for connecting the load to the floating battery is of the " make-before-break " type to avoid an interruption to the supply when changing over. Power failure and fuse alarms are provided on the equipment, the alarms being capable of extension to some staffed position when the power room is unattended.

With the ± 80 V supply, in order to limit bias distortion on telegraph signals it is essential that the terminal voltages of the positive and negative sides of the supply should not differ by more than 4 V. In addition, the voltage must be closely controlled to limit the flow of charging or discharging currents in the floating battery. To meet these conditions, automatic voltage regulators are fitted to the rectifiers or generators.

To avoid variations in the voltage of the H.T. and L.T. supplies—variations which would produce increased telegraph signal distortion—automatic carbon pile regulators are included in series with the supply to each of these loads: these are designed to maintain the anode supply within 130 V ± 1·3 V and the filament supply within 21·5 V ± 0·25 V. This arrangement is indicated in sketch (*b*). This regulator consists of a number of carbon discs, the mechanical pressure with which they are held together being controlled by a solenoid connected across the regulated supply. The carbon pile then behaves as a variable resistance, the regulator characteristics being designed to cover the known voltage variations of the battery supply and load.



(*b*)

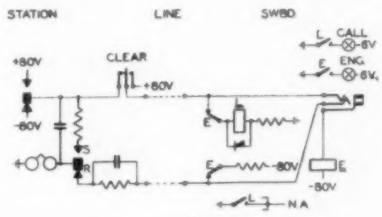
The 6 V supply may be provided as an A.C. supply from a stepdown transformer; one method of guarding against mains failure is to provide a small motor-alternator, which is automatically connected to the 160 V supply under this condition. Alternatively, a floating 6 V battery may be used in conjunction with a rectifier.

No special provision is made for such supplies as motors for conveyor bands whose operation is not essential to continuity of service.

Q. 7. Explain with the aid of suitable circuit diagrams the operation of a teleprinter switchboard installation, giving broadcasting facilities.

A. 7. The following description relates to a switchboard giving full intercommunication facilities on 70 lines, with broadcast facilities available on any group of 20 selected lines.

When a station calls by tapping the space bar of the teleprinter, relay L (sketch (*a*)), which is polarised by a metal rectifier, responds

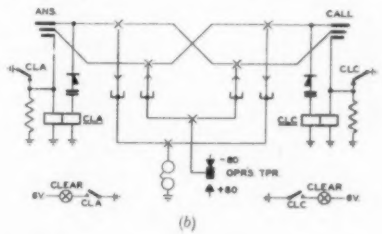


(*a*)

to positive elements of the signalling current and flashes the call lamp.

When the operator answers, by inserting an answering plug with the PRINT key already thrown and the position key in the ANSWER position, the sleeve relay E operates to the earth potential provided from the plug sleeve. Contacts of this relay disconnect the terminating equipment from the line and light the engaged lamps. The caller is then in communication with the operater by teleprinter. To complete a connection the operator inserts a call plug into the jack of the wanted line, provided the engaged lamp is not glowing. If required, the operator can communicate with the wanted station by moving the position key to the CALL position. Restoration of the PRINT key leaves the two lines connected for communication.

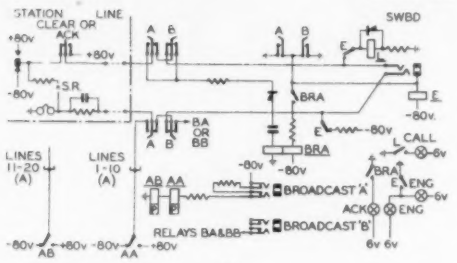
Either or both stations can send a clearing signal by depression of the CLEAR key, which sends a positive potential signal, for five seconds to operate the clear relay, CLA or CLC (sketch (*b*)). In



(*b*)

this circuit the capacitor is normally charged to the negative potential (−80V) present on the line, being little affected by short positive signal elements on account of the high resistance of the rectifier. The presence of a positive potential for five seconds, however, is sufficient to discharge the capacitor: on restoration of the CLEAR key the capacitor charges quickly in series with the relay and the forward direction of the rectifier to the negative potential. This charging current is sufficient to operate the relay which holds by removing the short-circuit across its second winding, in series with the E relay. The cord circuit supervisory lamps glow according to the receipt of a clear signal from either end.

Equipment for enabling any of 20 stations to receive broadcast messages is inserted in selected lines by jumpering on the I.D.F. (sketch (*c*)). The station wishing to transmit a broadcast message calls the switchboard: the operator inserts the call plug into a broadcast jack and throws the broadcast line keys into the corresponding A or B position. Signals from the transmitting station operate two polarised relays in series, AA and BB. A maximum of 10 lines, according to the keys thrown, is connected in parallel to the contacts of each polarised relay. On satisfactory reception



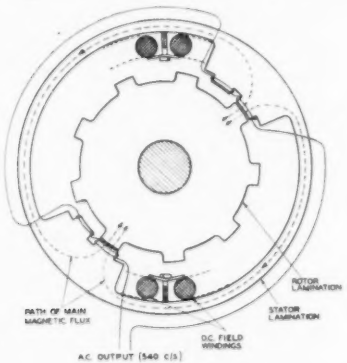
(*c*)

of the broadcast message each station throws the CLEAR/ACKNOWLEDGE key, operating the broadcast acknowledge relay BRA to light the ACK supervisory lamp; the BRA relay operates in an identical manner to the clearing supervisory relays. The transmitting station sends a clear signal and the operator takes down the connection and restores the broadcast keys.

Q. 8. Describe the principle of operation and the construction of the multi-frequency generator used in voice-frequency telegraphy. Describe the arrangements provided to maintain the frequency and power of the individual outputs constant within close limits.

A. 8. The multi-frequency generator used in voice frequency telegraphy is a rotating machine depending upon the generation of an E.M.F. in a system of stationary conductors when the magnetic flux threading them is varied. In this machine the rotor is simply a toothed disc of soft iron, rotating within the stator whose poles carry the output windings in which an E.M.F. is generated. Eighteen such sets of rotor and stator are provided in the machine, the flux being provided from a common polarising field which extends over the length of the generator. The generator is driven from a D.C. electric motor whose armature is upon the same shaft as the generator rotors; the motor field is distinct from the generator field.

Sketch (*a*) shows a cross-sectional view of the generator and illustrates the operation of the generator at one particular frequency,



(*a*)

namely, 540 c/s. The flux provided by the D.C. field windings takes the path shown through stator and rotor, each of which is laminated to reduce energy losses. The direction of winding the output coils is reversed on adjacent poles. As a rotor tooth passes a stator pole, then due to the changing airgap reluctance the flux in the pole rises to a maximum, and falls to a minimum value when the pole is between two rotor teeth. This rise and fall in flux cutting the output windings generates an alternating E.M.F., the teeth and poles being shaped in order to produce a reasonably pure sine-waveform. Since the rise in flux in one pole is accompanied by a fall in flux in the adjacent pole the total flux through the rotor remains sensibly constant; this condition is essential to prevent the induction of alternating E.M.F.s into the D.C. field and into the stator windings provided for the other frequencies.

The output frequency is determined by the number of rotor teeth and the rotor speed. In the example illustrated, the number of teeth is nine, and running at a speed of 3,600 r.p.m., this produces a frequency of $9 \times 3{,}600/60 = 540$ c/s: for the adjacent channel, 420 c/s, the rotor has seven teeth. The number of stator poles is not identical for all frequencies but the principle of maintaining a substantially constant flux for all positions of the rotors still holds.

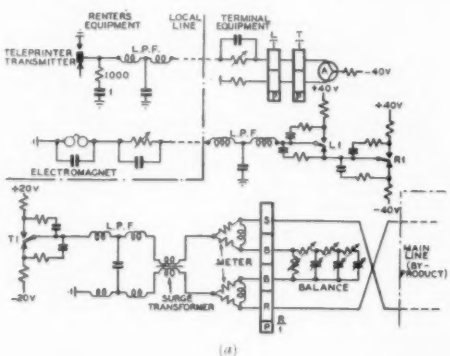
The frequency being a function of the speed of rotation, special attention is given to the maintenance of constant generator speed to keep the output frequencies within close limits. The driving motor is compound wound and its speed is accurately controlled by a centrifugal governor which regulates the current in the shunt field. A centrifugally-operated contact in the governor closes when the motor speed rises above the critical value and opens at any lower speed. When closed the contacts short-circuit a resistor in the field circuit and so increase the shunt field current and flux to slow down the motor.

The governor contact is mounted upon a disc at the end of the motor shaft. In order to prolong the life of the contacts and enable long running periods to be obtained between the occasions of contact cleaning and readjustment, the contacts are connected through a commutator with the object of reversing the current at each half revolution and reducing the contact build-up: a resistance network is inserted between the contacts and the commutator segments to give sparkless commutation. In addition, a thermionic valve is employed between the governor contacts and the field regulating resistance so that the direct load on the contacts is very small. The machine speed is checked by a stroboscopic disc illuminated by a neon lamp fed from a 1020 c/s oscillator; speed accuracy within a tolerance of $\pm 0{\cdot}25$ per cent. is obtained.

Each generator normally supplies up to ten systems, i.e. ten channels at each of the 18 frequencies. The output power is a function of the product of the load current and the terminal voltage, the latter depending upon both the generated E.M.F. and the load. The generated E.M.F. remains constant so long as the speed is uniform and the flux is constant; the field is energised from the same power supply which feeds the valve filaments of the voice-frequency equipment, this supply being automatically maintained constant between limits of $21{\cdot}5V \pm 0{\cdot}25V$. The power from the generator windings is fed into resistor networks to maintain a constant load: the output voltage is adjusted to $1{\cdot}0V \pm 0{\cdot}05V$.

Q. 9. Give a complete diagram of connections for one end of a teleprinter private wire, operating on a telephone by-product circuit. Explain the operation of the circuit, and give curves illustrating how the current varies at each end of the local line connecting the teleprinter transmitter to the control centre, when signalling is in progress. Explain the action of the spark quench circuit connected to the teleprinter transmitter.

A. 9. The required diagram of connections is given in sketch (*a*).



(*a*)

In the arrangement shown, single-current transmission from the renter's teleprinter is employed in order to simplify the equipment at his office and take advantage of a central battery system. At the equipment terminal two polarised relays L and T are joined in series and each is given a marking bias by passing a current through one winding of each relay. During space elements from the teleprinter both relays are operated to their space contacts by the preponderance

of current in the line windings. Contact T1 repeats the signals into the by-product main circuit. L1 repeats signals back to the renter to produce a local record on his page machine : these latter signals are by double current from a central ±40 V battery.

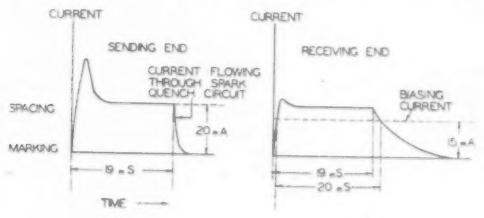
In the by-product circuit, double current signals are repeated at T1 from a ±20 V battery, this low value being used to limit the magnitude of transients and interference caused to the side circuits. To this end also the signals are transmitted through a balanced low-pass filter which cuts off at just over 100 c/s, and also through the primary winding of a surge transformer whose function is to introduce equal and opposite transients in the reverse path and so neutralise interference currents. The by-product portion of the circuit is designed for duplex operation by the use of an accurately adjustable balance network and by feeding the signals from T1 through the differentially connected receiving relay R. The balance resistance has twice the value of the by-product conductors, consequently transmitted signals sent through the single line winding S are neutralised by passing half-value signals through both balance windings BB. The receive-relay R responds according to the polarity of received signals in the winding marked R.

Received signals are repeated as double-current signals from the ±40 V battery at R1. Owing to the " half-duplex " connection of the R1 and L1 contacts in series, duplex service is not in fact possible, but alternative operation in either direction, i.e. simplex service, is provided, a receiving station being enabled to interrupt the local copy of the sending station, if necessary.

The required curves are given in the following sketches :—

Sketch (*b*) shows the sending end current from the renter's teleprinter transmitter (single current working).

Sketch (*c*) shows the current received at the control centre in the



line windings of the L and T relays. The prolongation of current after disconnection at the transmitter is due to the charging currents flowing into the filter and line capacitances. The dotted line indicates the selected value for marking bias current in order to prevent bias distortion. These two graphs relate to transmission at 50 bauds with an assumed transit time of 1 mS. (single current working).

When the circuit is broken by the transmitter tongue leaving the space contact the sudden cessation of the current in the filter coil would lead to the production of a very high induced voltage, causing sparking at the transmitter. The spark quench capacitor is provided to store the energy released from the filter coils, at a maximum current rate limited by the presence of the resistor in the spark quench circuit. The interchange of energy between the spark quench capacitance and the filter inductance gives rise to oscillatory currents : this energy is absorbed by the spark quench resistor.

Q. 10. *Explain how pictures may be transmitted by wire. Describe the arrangements adopted for phasing the sending and receiving equipments.*

What is the effect on the received picture of a difference in speed between the sending and receiving equipments? Calculate the maximum permissible percentage speed difference if the relative angular displacement of the two picture drums is not to exceed 2·4° after the transmission of a 12·5 cm. picture on an equipment giving 5½ lines per mm.

A. 10. In order to transmit a picture by wire the entire surface of the picture must be explored or scanned by a device capable of converting the resultant changes in light intensity into electrical signals suitable for transmission over a line. At the receiving end these signals must control a complementary device which scans a sheet of sensitive paper or film and records changes in impression thereon : these impressions must be recorded in synchronism with those at the transmitter in order that any given picture-element occupies the same relative position in both transmitted and received copies. For high grade work best results are obtained by the use of a beam of light to scan the transmitted picture, the reflected light being directed upon a photo-electric cell ; at the receiving end the signals may be applied to a mirror galvanometer reflecting a beam of light on to photographic film or paper.

In the Muirhead system of picture telegraphy the picture to be transmitted is wrapped around a drum and secured by a clip. The drum is driven at a constant speed of 1 r.p.s. by a phonic motor, this assembly being given at the same time a motion along its axis by a pawl and ratchet driving a lead screw. The drum moves in front of a fixed optical system from which a beam of light scans the picture in a close spiral of 135 lines to the inch. Reflected light from the picture passes through a rotating perforated " chopper " disc to the electrode of a photo-electric cell. The signal is modulated, the lower side-band selected and applied to the transmission line after amplification

At the receiving station the signal after amplification and demodulation is applied to the loop of a Duddel oscillograph which also has a local bias current to enable the most sensitive part of the range to be used. A beam of light from a projection lamp is reflected by the oscillograph mirror and arranged to sweep over a shaped mask ; a spot of light of size comparable to that used at the transmitter, and of intensity varying in accordance with the received signals, is brought to focus upon the revolving drum carrying the light-sensitive film or paper.

For correct reception the two picture drums must not only revolve at the same speed, but they must also be set in phase before transmission commences.

At either end the phonic motor is driven through a frequency divider from a 1,020 c/s valve-maintained tuning fork oscillator. To synchronise the oscillators at the two stations 1,020 c/s tone is sent over the line ; at the receiving end it is passed to the modulating grid of a cathode ray oscilloscope which also has the locally-generated 1,020 c/s supply fed through resistance capacitance components to the deflector plates.

Under these conditions half of the circular trace is suppressed : the display is stationary when the local oscillator frequency—after adjustment, if necessary—agrees with that from the distant station, a difference of 1 part in 10^6 being readily observable by this equipment. If carrier line circuits are used it is necessary to send a modulated " fork-tone " and to demodulate at the distant end in order that the 1,020 c/s tone transmitted shall be independent of any frequency change due to lack of carrier frequency synchronism over the carrier channel.

A cam and contacts upon the transmitter drum are used to send a phasing signal, once per revolution of the drum, consisting of a 30 mS. pulse of the 1,300 c/s tone used for modulating the picture signal. This phasing signal is transmitted only during the preliminary operation of setting the drums in phase prior to picture transmission ; subsequent phase accuracy during the transmission period of some 20 minutes is dependent upon the stability of the tuning fork oscillators. At the receiving end the phasing signal is amplified and fed, under the control of a press button and relay, to an anode bend detector in whose anode circuit is a high-speed relay. Contacts of this relay close a circuit for the release of the electromagnetic pawl clutch of the receiving drum.

The effect of a difference in speed between the sending and receiving equipments would be to distort the received picture due to the cumulative phase difference between the rotating drums. Any straight axial line on the transmitted picture would be recorded as a curved line at the receiver, the curve tending towards a spiral as the speed difference increased.

At 5½ lines/mm., the number of lines in a 12·5 cm. picture is $(125 \times 5\frac{1}{2})$. For a maximum angular displacement of 2·4° the displacement per line is $2{\cdot}4/(125 \times 5\frac{1}{2})$.

Permissible percentage speed difference

$$= \frac{2{\cdot}4 \times 100 \times 3}{360 \times 125 \times 16} = \frac{1}{1000} = \underline{0{\cdot}1 \text{ per cent.}}$$

CORRECTION.—*In Supplement No. 2, July* 1950, *Line Plant Practice I,* 1950, *the Note concluding A.1 on p.* 41 *should have read:—*

"Bare telephone wires are not nowadays erected to cross over power wires unless the uppermost wire on the power line is earthed and forms a satisfactory guard. The method described above would serve equally well whether the crossing was under or over the power wires. In the former case, it would prevent the telephone wire springing upwards into contact with a power wire or, on a windy day, being blown upwards into contact with it. In the latter case, it would prevent the telephone wire sagging on to the power conductors. The modifications of the method when a telephone wire is to cross under power wires will be obvious."

MODEL ANSWERS

TO

CITY AND GUILDS OF LONDON INSTITUTE EXAMINATIONS

Students preparing for City and Guilds examinations in Telecommunications will find the Model Answers published in book form a useful aid to study. The questions and answers have been extracted from Supplements to the Journal issued during recent years, and, after careful revision, have been grouped under headings corresponding with the new syllabuses introduced by the City and Guilds in 1947.

Model Answers to questions which, on account of paper shortage, were unanswered during the war years are also included.

The following books have been published to date :—

TELECOMMUNICATIONS (PRINCIPLES) I

TELECOMMUNICATIONS (PRINCIPLES) II

RADIO I *(Temporarily out of print)*

TELEGRAPHY I

TELEPHONE EXCHANGE SYSTEMS II

(PRICE 2/6 EACH POST FREE, 2/9)

RADIO II

TELEGRAPHY II

TELEPHONE EXCHANGE SYSTEMS I

(PRICE 3/6 POST FREE, 3/9)

Orders may be placed with the JOURNAL LOCAL AGENTS or with THE MANAGING EDITOR, POST OFFICE ELECTRICAL ENGINEERS' JOURNAL, Alder House, Aldersgate Street, London, E.C.1.

Printed by SANDERS PHILLIPS & CO., LTD., The Baynard Press, Chryssell Road, London, S.W.9, and Published by BIRCH & WHITTINGTON (*Prop. Dorling & Co. [Epsom], Ltd.*) Epsom, Surrey.

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

Vol. 44 April 1951 Part 1

Acceptance Testing of Coaxial Pairs for the Inland Trunk Network

R. E. TAYLOR, A.M.I.E.E., and
R. J. TURNER, B.Sc.(Eng.), A.M.I.E.E.†

U.D.C. 621.315.212 : 621.397.5 : 621.395.741

To ensure that coaxial pairs meet specified requirements, acceptance tests are required as outlined in this article. The equipment and methods described were employed on the London-Birmingham television cable for measurements at frequencies up to 26 Mc/s.

Introduction.

IN general, trunk cables containing coaxial pairs are ordered by the Post Office on a basis which provides for the laying of the cable by the manufacturer. The cable is then accepted or rejected in so far as the coaxial pairs are concerned on the results of measurements made on repeater sections of cable, which are generally from 3 to 6 miles long. Cables are manufactured in lengths of about one-tenth of a mile to a factory length specification ; the cable is then laid and terminated, and complete overall tests are made on each repeater section of cable. The most important side of Post Office measurement work in connection with the initial testing of coaxial cables is thus concerned with repeater section lengths of cable. When new types of cable are being introduced, however, measurements are required on factory lengths of cable and for such measurements a different technique is required.

The frequency range over which the measurements are to be made depends largely on the diameter of the coaxial pair under consideration. Thus, for the 0·375-in. diameter coaxial pairs, which form a large part of the trunk network, acceptance tests up to 3 Mc/s are required. The introduction of 0·975-in. diameter coaxial pairs[1] has necessitated an extension of the testing range up to 26 Mc/s.

Test Specifications for Coaxial Pairs

As measurements for acceptance tests are bound up with the requirements of test specifications, some consideration will first be given to methods of specifying the requirements for coaxial pairs in cables for Post Office use. The cable whose performance is to be specified consists, in general, of a number of coaxial pairs, sometimes of differing sizes, with their outer conductors insulated from one another, together with ordinary pairs, all enclosed in a lead sheath. The specification and testing of ordinary pairs follows well-established practice and no further details will be given in this article. It may be noted, however, that it is usual to provide power for some repeater stations by feeding 50 c/s alternating current supplies over the coaxial pairs. It is thus necessary to make measurements to ensure that the noise level on the ordinary pairs is not excessive.

The performance of a uniform coaxial pair is completely specified by the resistance, inductance, conductance and capacitance per unit length. It can also be completely specified by the dimensions of the conductors and the conductivity, permeability and permittivity of the conductors and the dielectric. It is more practical, however, to specify the resistive and reactive component of the characteristic impedance, the attenuation coefficient and the phase-change coefficient ; for some purposes it is more convenient to deal in terms of relative velocity rather than the phase-change coefficient. All these parameters are functions of frequency, and, provided the frequency is not too low, are given by the following relations :—

$$\alpha = A\sqrt{f} + Bf \quad \ldots\ldots (1)$$

$$\rho = \rho_1 - D/\sqrt{f} \quad \ldots\ldots (2)$$

$$Z_0 = R_1 + (1-j)H/\sqrt{f} \quad \ldots\ldots (3)$$

where α is the attenuation coefficient,

ρ is the relative velocity,

Z_0 is the characteristic impedance,

f is the frequency in Mc/s,

and A, B, ρ_1, D, R_1 and H are constants for a particular coaxial pair.

Owing to inevitable variations in the dimensions of the coaxial pair and to irregularities in the properties of the conductors and the dielectric, the characteristic impedance and propagation coefficient vary along the length of a coaxial pair. It is thus necessary, particularly for pairs to be used for television purposes, to apply limits to these irregularities or to their effects. Ideally the smooth curve to be expected from the variation of the input impedance with frequency of a long terminated line should follow equation (3) ; due to the irregularities in the cable, however, this curve has superimposed on it variations in both the resistive and reactive components. In Post Office practice the resistive component of the input impedance is measured ; limits are then placed on the permissible amount of deviation of the irregular curve that results, from a mean curve drawn through it. Limits are also applied to the value of the smooth mean curve at a particular frequency.

In Post Office specifications the attenuation of a repeater section at acceptance is required to be within certain limits of the attenuation given by a relation similar to equation (1). The attenuation of a cable changes with temperature and the measured attenuation of the cable must be corrected to allow for this.

Where there is more than one coaxial pair in a cable, the question of cross-talk between them arises. In Post Office specifications, the minimum permissible cross-talk attenuation is quoted by laws similar to the following :—

$$\alpha_n = J + K\sqrt{f} \quad \ldots\ldots (4)$$

$$\alpha_f = M + N\sqrt{f} \quad \ldots\ldots (5)$$

†The authors are respectively Factories Executive Engineer, Factories Dept. (formerly with Test and Inspection Branch, E.-in-C.'s Office), and Executive Engineer, Radio Experimental and Development Branch, E.-in-C.'s Office.

[1]Stanesby, H., and Weston, W. K. "The London-Birmingham Television Cable." *P.O.E.E.J.*, Vol. 41, p. 183 ; Vol. 42, p. 33.

where a_n and a_f are the near-end and far-end cross-talk, respectively, and J, K, M and N are constants for the two coaxial pairs concerned.

Acceptance Tests on Repeater Section Lengths

General.

In testing a repeater section length of a cable containing both coaxial pairs and ordinary pairs, the order of carrying out the tests is of importance since it would be a waste of time to carry out high-frequency tests on the coaxial pairs when there may be a contact fault or low insulation resistance on the ordinary pairs which would necessitate rejection of the section, with perhaps the need to replace a drum length of cable. When a length has to be replaced after acceptance tests have commenced, it is, of course, necessary to repeat all the tests so far made. The order of testing shown below has been found to be sound practice to ensure that simple but important faults are found early on by means of D.C. tests which do not take long to carry out.

(1) Resistance of all conductors
(2) Insulation breakdown on coaxial pairs
(3) Insulation resistance of all conductors
(4) Attenuation of the coaxial pairs
(5) Impedance and/or reflection coefficient of the coaxial pairs from both ends of the section
(6) Cross-talk between coaxial pairs
(7) Attenuation of ordinary pairs
(8) Cross-talk between ordinary pairs.

The tests concerned with the coaxial pairs will be described in turn.

Conductor Resistance.

There are two reasons for making accurate measurements of conductor resistance. The first is to check that no high resistance joints have been made during installation ; the difference between the resistances of any two inner conductors is specified not to exceed 0·2 ohm for a repeater section of 0·375-in. coaxial pair, and any value higher than this is specially investigated by comparison with the values obtained on drum lengths at works. The second reason is that, since the resistance of the inner conductor varies with temperature and is stable with time, it can be used to assess the mean temperature of a cable ; the measured resistance of the inner conductor is compared with that calculated from measurements made on factory lengths of cable at a known temperature by making use of the known value of the coefficient of variation of resistance of copper with temperature. The length of the cable when jointed is less than that at the contractor's works and allowance must be made for this.

The resistances to be measured are small in magnitude, being 5·0 and 3·5 ohms per mile at 10°C for the inner and outer conductors, respectively, of the 0·375-in. diameter coaxial pair. It is thus important to allow for the resistance of the test leads and to ensure that there are no troubles due to contact resistance at the points of connection of the test leads. To this end, special connectors which can be tightly clamped to the cable termination are employed. To obtain consistent results and to check that there are no high resistance difficulties, it is customary to deal with two coaxial pairs at a time and take all six combinations of the four conductors looped two at a time at the far end with a connection of known resistance ; from these results the sum of the resistances of all four conductors can be obtained in three different ways and any discrepancy shows up connection troubles.

Insulation Breakdown.

The insulation breakdown test is used to detect incipient contacts between the inner and outer conductors of the coaxial pair due to slivers of copper, metallic dust or faulty joints. An A.C. supply at 2,000V, 50 c/s is applied between the inner and the earthed outer conductor for a period of two minutes. The test is used extensively by the contractor during installation and is made jointly by the Post Office and the contractor for the acceptance test.

One form of the apparatus for this test consists of a battery-driven motor alternator feeding a 50 c/s voltage to a step-up transformer. The output voltage and current are indicated by a 3-kV electrostatic voltmeter and by a milli-ammeter, and the voltage is controlled by a rheostat in the field circuit of the alternator. The voltage applied to the cable is increased from zero to 2 kV and then maintained at this value for two minutes. The whole of the equipment is mounted in a jointer's truck and long leads are used to connect to the cable end.

A disadvantage in using an alternating voltage supply is that a fairly high current is normally taken by the pair under test and fault currents may pass unnoticed. In the future it is proposed to use 3 kV direct voltage for the test.

The elaborate safety precautions employed on complete coaxial systems to prevent access to the cable pair while it is carrying current are not available when these breakdown tests are made, and it is, therefore, the practice to arrange for a responsible person to be at the remote end of the repeater section under test and in telephonic communication with the tester to ensure that the cable end is not touched while under test.

Insulation Resistance.

Measurements are made of the insulation resistance of the coaxial pair to check that the insulation has not been affected by moisture.

A 500-V motor-driven ohmmeter is used and the insulation resistance of each conductor in the cable is measured between that conductor and all other conductors and the cable sheath which are connected together and to earth. When testing on short sections, this test is sometimes not sensitive enough, and in such cases the high direct voltage required is obtained from batteries and applied to the cable through a sensitive galvanometer.

Attenuation.

It is the practice to make attenuation measurements on all coaxial pairs over their working frequency range on every repeater section length ; two coaxial pairs are dealt with at a time, the far ends being looped together with a short length of flexible coaxial pair. It is required to deduce the attenuation per mile corrected to a specified temperature, and the accuracy of the result depends not only on the accuracy of the measurement of the attenuation but also on the accuracy with which the length and the temperature at the time of test can be assessed.

As already described, the temperature of the cable is calculated from the resistance of the inner conductor. The attenuation of a coaxial pair is proportional to its high-frequency resistance which, at the frequencies concerned here, is proportional to the square root of the resistivity ; it follows that the coefficient of change of attenuation with temperature is one-half that of the temperature coefficient of resistance of the conductors.

The distance between the centres of manholes is measured to the nearest foot, i.e. $\pm$ 6 in., and this, together with a knowledge of the additional length of cable used in following the contour of the walls of the manholes, gives the length of a repeater section to about $\pm$ 0·1 per cent. This measurement is not necessarily the true length of the cable, however,

because, apart from inaccuracies in the many separate measurements involved, no allowance is made for the increase in length due to the varying depths at which the cable is laid. The importance of this factor varies and is greatest in built-up areas where the changes in depth are likely to be more severe. It may be remarked here that the practice of including a length-tape in a cable has advantages; the length of the individual lengths can then be assessed at the time of jointing, the only uncertainty being the amount the cable has stretched during pulling in—a factor that normally should be negligible.

The attenuation of the coaxial pair (i.e. the attenuation coefficient $\times$ the length) is measured on an insertion loss basis. The attenuation is equal to the insertion loss only when the latter is measured between impedances equal to the characteristic impedance of the cable. The error is negligible, however, if the terminating resistors are within a few per cent. of the characteristic impedance, as is likely in these tests, but if one termination is in error by 5 per cent. and the other by 50 per cent. then the error can be as much as 0·14 db.

The maximum value of attenuation to be measured is, of course, that of the longest length at the highest frequency at which measurements are required. For 0·375-in. diameter coaxial pairs the attenuation of a looped 6-mile repeater section is about 80 db. at 3 Mc/s. For a looped 3-mile repeater section of 0·975-in. pair the attenuation is 50 db. at 26 Mc/s. In some circumstances, repeater sections as short as a mile are encountered and hence the minimum attenuation to be measured is the attenuation of this length of 0·975-in. pair at the lowest frequency at which measurements are required; this frequency is 1 Mc/s and the attenuation of the looped section is only 3 db.

For the 0·375-in. coaxial pairs, attenuation measurements are made over the frequency range 60 kc/s–3 Mc/s at intervals of 20 kc/s at the lower frequencies and at wider frequency intervals at higher frequencies.

The apparatus used consists of an oscillator feeding into two 0–61·5db. attenuators, A and B, in parallel (see Fig. 1). The coaxial pairs under test are connected in series with

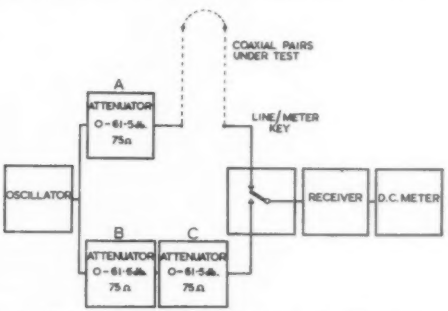


FIG. 1.—BLOCK SCHEMATIC DIAGRAM OF EQUIPMENT FOR ATTENUATION TEST UP TO 3 Mc/s.

attenuator A and a further attenuator, C, is connected in series with attenuator B. The voltage at the output of the return coaxial pair is compared with that at the output of attenuators B and C by means of a super-heterodyne receiver of the communications type having an input impedance of 75 ohms; the intermediate frequency heterodyne oscillator is used to produce an audible beat note which is rectified at the output of the receiver and indicated by a sensitive D.C. meter. The comparison of the two voltages is facilitated by a changeover key which copies mechanically the action of plugging the receiver lead into the coaxial pair or the attenuators.

Attenuator A is kept at as high a value as possible in order to present a 75-ohm source impedance to the coaxial pair under test. To make a measurement, attenuators B and C are adjusted so that the same meter reading is obtained in both positions of the Line/Meter key. These attenuators are variable in steps of 0·5 db. and the attenuation of the coaxial pair is obtained to the nearest tenth of a decibel by interpolation with reference to the meter. It will be seen that in this method the output not connected to the receiver is open-circuited. The effect of this on the oscillator output voltage is small, however, since the attenuation in both the cable side and in the measuring side is always kept as high as possible.

On the 0·975-in. coaxial pair measurements of attenuation are taken over the range 1–30 Mc/s at frequency intervals of 1 Mc/s up to 5 Mc/s, and thereafter at intervals of 5 Mc/s. The method of measurement is in principle the same as that used at lower frequencies, but the oscillator and reference attenuators are replaced by a signal generator that has been developed for the purpose. The instrument gives two outputs from a crystal oscillator incorporated in it, and one of these outputs can be varied by means of an accurate piston attenuator.[2]

Characteristic Impedance.

For repeater section lengths of coaxial pair, the input impedance when the far end is terminated in the approximate value of the characteristic impedance is taken as the value of the characteristic impedance. The error in taking the input impedance to be the characteristic impedance depends upon the attenuation of the line and the closeness of the terminating resistance to the characteristic impedance. Thus, if the terminating resistance is within one per cent., the error in taking the input impedance of a line of attenuation 20 db. to be the characteristic impedance will be 0·01 per cent. and will be negligible compared to the measurement error.

The value of the input impedance varies with frequency in two ways; the impedance decreases as the frequency increases owing to full establishment of skin effect; superimposed on this smooth decrease are irregular variations due to the non-uniformity of the coaxial pair. To determine as far as possible the maximum impedance excursion of these irregularities, it is necessary to take readings at small frequency intervals. Thus, for the 0·375-in. coaxial pair, readings are taken over the frequency range 60 kc/s –3 Mc/s at 20 kc/s intervals; for the 0·975-in. pair, readings are taken at 20 kc/s intervals over the range 3–10 Mc/s and at 40 kc/s intervals from 10–26 Mc/s, a total of 750 measurements. To make such large numbers of measurements, a direct-reading bridge which is accurate, quick to operate and independent of frequency is necessary. It need have only a limited range above and below 75 ohms.

A bridge developed for this work[3] employs capacitive ratio arms C_3, C_4 (see Fig. 2); the unknown impedance

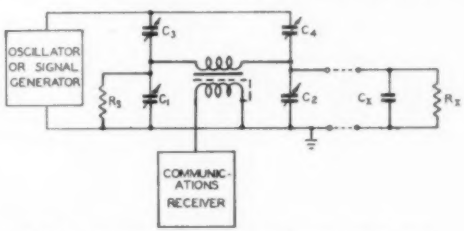


FIG. 2.—SIMPLIFIED CIRCUIT OF IMPEDANCE BRIDGE.

[2] *P.O.E.E.J.*, Vol. 43, p. 192.
[3] British Patent Application No. 10375, 1948.

represented by the shunt combination of R_x and C_x is connected in parallel with a variable capacitor C_2 and the fourth arm of the bridge consists of a standard resistor, R_s, in parallel with a variable capacitor, C_1.

When the bridge is balanced it can be shown that

$$R_x = (C_3/C_4)\, R_s \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$\text{and } C_x = C_1\ (C_4/C_3) - C_2 \quad \ldots\ldots\ldots\ldots (7)$$

The resistor R_s is of a plug-in type arranged in a coaxial mounting and consists of a high stability carbon resistor of resistance corresponding to the mean of the range to be measured. The capacitances C_1 and C_2 are formed by the two halves of a differential capacitor. A second differential capacitor C_3, C_4 provides the resistance balance and the dial is directly calibrated in terms of resistance. To check the calibration before using the bridge, a high stability carbon resistor, of which the D.C. resistance is known, is connected to the unknown terminals of the bridge and a balance made at a convenient low frequency. Allowance can then be made for any change in the value of the standard resistor with temperature and/or time by bodily rotating the resistance scale after loosening the clamping screws. Two types of the bridge have been developed, one for the range 60 kc/s–5 Mc/s and the other for the range 2–40 Mc/s.

An early model of the bridge for the range 60 kc/s–5 Mc/s covers two resistance ranges. The lower scale on the dial, which is concerned with the work described here, covers the range 66–83 ohms, with a standard resistor of 75 ohms, for a capacitor rotation of 180 deg. By using a standard resistor of 60 ohms, the upper scale may be used to cover the range 53–67 ohms, for work on submarine coaxial cables of nominal impedance 60 ohms. The capacitor C_3, C_4, which provides only a small variation of capacitance above a large fixed value, has only a few semi-circular plates, the remaining plates being full circles. The transformer from the bridge to the detector is balanced and screened ; it has two screens, one of which is earthed. The pair under test is connected to the bridge by a flexible cable not longer than 5 ft., and provided the characteristic resistance of the flexible cable is within ± 4 per cent. of the resistance being measured, the error at 3 Mc/s caused by the connecting lead will not exceed ± 0·2 per cent. When a frequency run is being made, the presence of the lead shifts the frequencies at which maxima and minima occur, but affects their magnitudes to only a slight extent ; hence the actual error due to the lead in measuring impedance excursions is less than indicated above and is not of practical importance.

The bridge for the frequency range 2–40 Mc/s is shown in Fig. 3. To obtain the small change of capacitance on a fairly large fixed value for C_3, C_4, a cam and lever mechanism is employed. One advantage of this is that by suitably shaping the cam, a linear scale can be obtained ; also, the capacitors can be mounted close together with the control knobs spaced apart, and in addition, about 350° rotation of the control knob can be obtained with consequent lengthening of the scale. When measuring at high frequencies, it is essential to connect the bridge to the coaxial pair under test by the shortest possible lead. In practice, a flexible lead only 6 in. long is used, and as before, provided the characteristic resistance of the flexible cable is within ± 4 per cent. of the resistance being measured, the error at 26 Mc/s caused by the connecting lead will not exceed ± 0·2 per cent. As the cable end is normally 6 ft. 6 in. from the ground, the tester has to operate the bridge from a high chair with a suitable support for the bridge. Even so, this form of bridge, together with the one for lower frequencies, is so easy to operate that an experienced tester can make more than 300 measurements in an hour without undue fatigue.

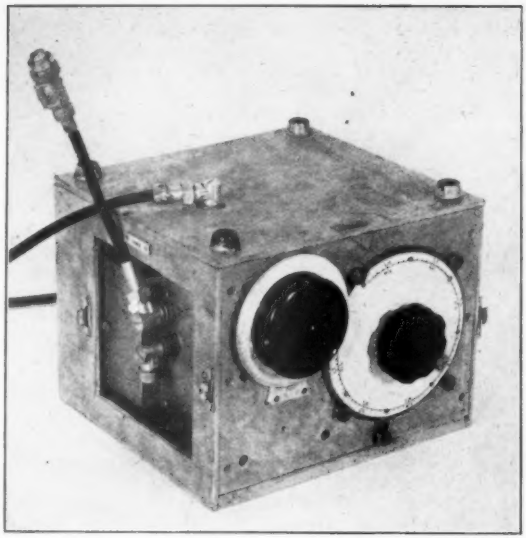


FIG. 3.—PROTOTYPE IMPEDANCE BRIDGE FOR USE IN FREQUENCY RANGE 2–40 Mc/s.

Reflection Coefficient.

Although the bridges described above are quickly and easily operated, a method involving a continuous frequency sweep would much reduce the testing time. This implies that the quantity to be measured and the method of measurement must be such that the result can be exhibited continuously by the deflection of a meter. A quantity that lends itself to measurement in this way is the modulus of the reflection coefficient of an unknown impedance Z with respect to some specified reference resistance R.* This quantity forms a convenient measure of the amount by which Z differs from R ; it is approximately proportional to the impedance deviation $|Z - R|$ when the latter is small.

The reflection coefficient can be measured by means of a bridge network that satisfies two simple conditions : the bridge must be balanced when the reference resistance R is connected to the "unknown" terminals, and the impedance looking into the unknown terminals must be equal to R. The second of these conditions need only be approximately met if the values of reflection coefficient to be measured are small. Then, if an impedance Z is connected to the terminals in place of R, the out-of-balance voltage from the bridge is proportional to the reflection coefficient of Z with respect to R. This principle is used in apparatus designed to measure the modulus of the reflection coefficient of the input impedance, Z, of a terminated coaxial pair with respect to a resistance, R, which is chosen to have the expected mean value of the characteristic impedance.

In addition to the bridge it is necessary to have a source of power and means of amplifying the out-of-balance voltage and indicating its magnitude. A block schematic diagram of the complete arrangement is shown in Fig. 4; most of

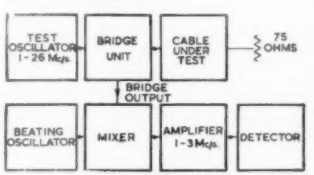


FIG. 4.—BLOCK SCHEMATIC DIAGRAM OF EQUIPMENT FOR REFLECTION CO-EFFICIENT TEST.

*The reflection coefficient is regarded as a property of the impedance Z with respect to the reference resistance R and does not imply the existence of echo signals such as are observed in pulse testing.

the units are conventional, but the following details of the bridge may be of interest. It is made up in a small unit (Fig. 5) which is connected to the rest of the equipment

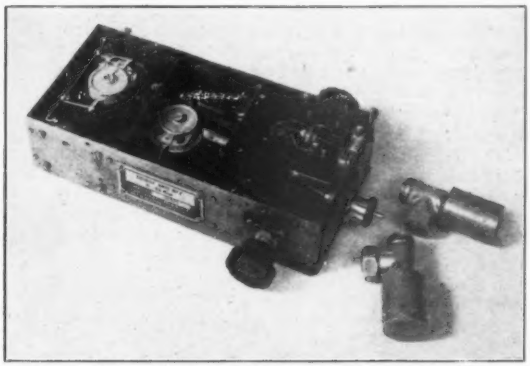


FIG. 5.—BRIDGE UNIT FOR REFLECTION COEFFICIENT TEST.

with flexible cables; thus, it can be plugged directly into the cable under test. This feature is an asset when cable terminations are situated some distance from the ground. A screened and balanced input transformer T_1 (Fig. 6)

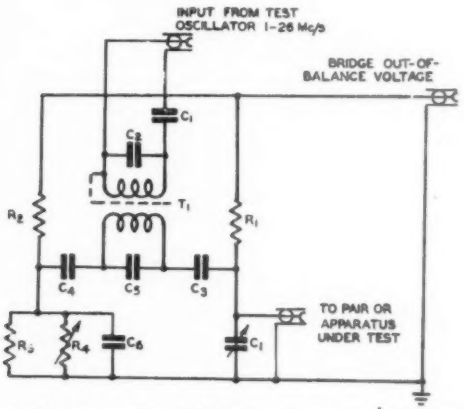


FIG. 6.—CIRCUIT OF BRIDGE UNIT FOR REFLECTION COEFFICIENT TEST.

provides a balanced supply to the bridge; two types of transformer are used—one covering the range 1–7 Mc/s, and the other the range 4–26 Mc/s. The bridge arms consist of two high stability carbon resistors R_1 and R_2; the impedance under test is connected across a variable capacitor C_1, and the fourth arm consists of a fixed resistor R_3, a variable resistor R_4, and a fixed capacitor C_6 in parallel.

The remainder of the apparatus is largely standard equipment. A test oscillator covering the range 1–26 Mc/s feeds into the bridge unit. The output from the bridge is taken to a linear frequency changer where it is mixed with a supply from a beating oscillator to give a signal which is in the range 1–3 Mc/s.* This signal is fed to an amplifier which has a response flat to $\pm$ 0·1 db. over the frequency range 1–3 Mc/s; the output is rectified and measured on a microammeter.

Tests are made over frequency bands 2 Mc/s wide; thus, to measure the reflection coefficient over the range $f \pm 1$ Mc/s the test oscillator is set to f Mc/s and the beating oscillator to $f + 2$ Mc/s. A difference frequency of 2 Mc/s then passes to the amplifier. A resistance of the value of the expected mean impedance of the cable under test (the reference resistance R_0) is connected to the "unknown" plug of the bridge and the bridge balanced by means of the controls, R_4 and C_1. The equipment is calibrated by connecting in place of R_0 a resistance giving a known reflection coefficient with reference to R_0, and varying the gain of the apparatus to obtain the correct reading. The apparatus is then ready for use; the coaxial pair under test is connected to the unknown terminals and the test oscillator swept through the frequency range $f \pm 1$ Mc/s.

The meter reading gives the reflection coefficient directly to an accuracy of $\pm$ 10 per cent. provided the test oscillator output remains constant throughout the sweep. Thus, when the impedance deviation is 1·5 ohms, the accuracy of measurement is $\pm$0·15 ohm. For a measurement at the frequency at which the bridge is balanced, the accuracy is greater.

As mentioned previously, the type of specification at present used limits only the variation of the resistive component of the input impedance. Thus, since the reflection coefficient apparatus also takes account of the reactive component of the input impedance, results obtained with it cannot be interpreted directly in terms of the specification. Thus, suppose that for a particular coaxial pair it is specified that the resistive component of the input impedance at any frequency in the band tested shall not differ by more than $\pm$ 3 per cent. from the value, at that frequency, of the smooth mean curve drawn through the plot of the resistive component of the input impedance. Ignoring the smooth variation of impedance with frequency the above tolerance indicates that if the reflection coefficient does not exceed 0·015 then the specification is met. However, the reflection coefficient might considerably exceed 0·015 due to the reactive component of the input impedance without the resistive component exceeding the specified tolerance; such a case would meet the present specification requirements.

It has been the practice to employ the reflection coefficient apparatus as a quick means of testing each end of each 0·975-in. coaxial pair in the frequency range 3–26 Mc/s. From the results so obtained on a given repeater section it has been possible to select the pair which was likely to give the worst results for impedance, and full impedance frequency tests have been made from one end on this pair only, unless it was thought from experience that other pairs also warranted impedance tests.

Crosstalk Attenuation.

The measurement of crosstalk attenuation is a special case of the measurement of insertion loss in which losses of up to 165 db. are to be measured. The attenuation to be measured increases with frequency. Measurements are made from 60 kc/s to a frequency where the attenuation is outside the limit of measurement; this frequency is seldom higher than 1·5 Mc/s. A method similar to that described for attenuation measurement is used, the arrangement being as shown in Fig. 7. To increase the maximum attenuation measurable an oscillator with a power output of about 5 watts is used and the range of the attenuators increased. To prevent damage to the attenuators by the high power used, they are preceded by a 7,425-ohm series resistor, which, with the 75-ohm input impedance of the attenuator gives 40db. attenuation; this arrangement is admissible

* The arrangements described apply strictly to tests over the frequency range 5-26 Mc/s; for the range 1–5 Mc/s certain modifications are made.

at the low frequencies at which measurements are required, but would become inaccurate at high frequencies owing to stray capacitances. Sometimes, to economise in the use of attenuators, an 80db. pad is used, made on the same principle, but employing two stages. For near-end crosstalk the attenuation is measured between the adjacent ends of two coaxial pairs with the far ends terminated in 75-ohm screened resistors of an adequate power rating. For far-end crosstalk measurements the oscillator feeds into the near end of the disturbing pair and the near end of the disturbed pair of the cable is terminated in a 75-ohm resistor. The attenuation is measured between the

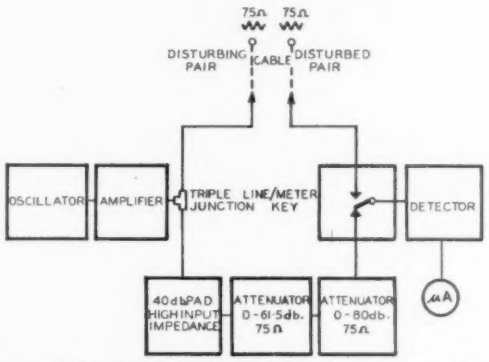


FIG. 7.—BLOCK SCHEMATIC DIAGRAM OF EQUIPMENT FOR CROSSTALK TEST.

Connections shown for near-end tests. For far-end crosstalk measurements the oscillator and amplifier are moved from the position shown and connected in place of the resistor terminating the disturbing pair.

terminated far end of the disturbing pair and the far end of the disturbed pair; the attenuation of the section of coaxial pair is added to the measured value of attenuation to obtain the value of the far-end crosstalk attenuation.

For check measurements covering the frequency range up to 26 Mc/s a piston attenuator is used as the reference attenuator; the outer conductor of the coaxial connecting leads for the equipment are made from annealed copper pipe to ensure that no leakage occurs from this source.

DESIGN OF EQUIPMENT FOR ROUTINE ACCEPTANCE TESTING

In the design of equipment for the routine acceptance testing of coaxial pairs, due consideration must be given to the conditions under which the equipment is used. These are often far from ideal and the simpler the operation of the equipment the easier it is to obtain the required accuracy of measurement. The apparatus has to be loaded and unloaded to and from test vans frequently and has to travel with little or no packing. Hence the equipment should be in units which can be handled easily, which are light and compact but which are robust. Since mains supplies are often not available, the power consumption of the equipment should be kept to a minimum and suitable portable power supplies should be included in the equipment of a testing group.

With regard to the future development of equipment, it may be possible to reduce the number of units of equipment required and simplify operation by the development of a combined oscillator and detector unit. The type of unit envisaged would have a single control to alter the oscillator frequency and to tune the detector at the same time; such a unit would save time in the measurements of impedance and insertion loss.

The same basic type of unit is applicable to the reflection coefficient measuring apparatus, but in this case the output level of the oscillator must be maintained constant. With reflection coefficient equipment an ideal arrangement would be to have an automatic recording of reflection coefficient against frequency.

The reflection coefficient apparatus has hitherto been used mainly at frequencies above 3 Mc/s and the reflection coefficient has been measured with respect to a fixed resistor having a value equal to the expected mean resistance of the pair. If the use of the equipment is to be extended to lower frequencies the reflection coefficient should be related to the true characteristic impedance of a uniform coaxial pair which changes appreciably at the lower frequencies. A network can be designed to simulate closely this impedance and the bridge can be arranged to measure the reflection coefficient relative to this impedance by replacing R_1 (see Fig. 6) by this simulating network; the impedance against which the bridge is initially balanced should also be a simulating impedance.

ORGANISATION OF ACCEPTANCE TESTING

The amount of coaxial acceptance testing varies greatly from time to time. To economise in the provision of testing equipment it has been found that a good way of organising the work of acceptance testing a long cable is to divide the work into portions. Thus, for the London-Birmingham television cable[1] the work was divided and carried out by four testing groups. The first group working in advance of the others carried out conductor and insulation resistance tests on all conductors, insulation breakdown tests on all coaxial pairs and attenuation and reflection coefficient tests on the 0·975-in. pairs in the frequency range 3–26 Mc/s. The second group made such impedance tests as were necessary on the 0·975-in. pairs over the frequency range 3–26 Mc/s; at least one impedance/frequency run was made on each 3-mile repeater section. The third group carried out all the remaining tests on the coaxial pairs, namely, the impedance and attenuation on the 0·375-in. pairs, and crosstalk on all combinations of the coaxial pairs. The fourth group dealt with the tests on the ordinary pairs.

At the time of acceptance tests, there was often no main electricity supply available at the repeater stations. Hence each testing group had a 1-kW petrol generator supplying 230V A.C. To make each group self-sufficient and mobile such items as tables, chairs, lights and heating stoves were included in their equipment. To facilitate connection of equipment comprehensive sets of test leads were carried together with all the connectors, adaptors, terminations, leads and spanners necessary.

ACKNOWLEDGMENTS

Most of the apparatus described has been developed in the Radio Experimental and Development Branch and in the Test and Inspection Branch. The authors wish to express their thanks to their colleagues for their help in the preparation of the paper and to Standard Telephones & Cables, Ltd., for permission to publish information on their high voltage breakdown test.

A New Portable Generating Set for Manhole Lighting

B. C. HILL, B.Sc.(Eng.), A.M.I.E.E., and
E. E. M. SMITH, A.M.I.E.E.†

U.D.C. 621.311.28 : 628.9 : 621.315.233

The new "Generator, P.E.D., Portable," described in this article, is for use in conjunction with a 24-V battery to give improved lighting of manholes. The automatic voltage regulation is such that a compensated output voltage characteristic is obtained, making the plant suitable both for battery charging, and for possible use in operating equipment such as cable driers and soldering irons.

Introduction.

FOR many years the acetylene lamp has been the standard means of lighting Post Office underground plant. It has long been realised, however, that this method of illumination, although providing adequate light, has a number of disadvantages, e.g. the risk of ignition of combustible gases, the emission of fumes and heat which may be distressing to operators when the lamp is used in a confined space and the difficulty in disposing of spent carbide.

Prior to 1939, efforts were made to develop a suitable portable electric lamp, and field trials were conducted with the " Handlamp, Electric, No. 3A," but it was found that the illumination provided was insufficient and difficulty was experienced in providing charging facilities.

At the outbreak of war further development work was abandoned, and it was not until 1945 that the matter again came under active consideration. It then appeared that the only satisfactory method of obtaining an adequate light in manholes for prolonged periods was by a portable generating set, and experiments were carried out under practical conditions with a petrol-engine-driven set lent by a manufacturer ; promising results were obtained.

In 1946, however, supplies of war-surplus petrol-engine-driven battery charging sets became available, and after examining a number of types, it was decided that a 24V, 300W set of U.S.A. manufacture was the most suitable for the Department's purpose. The set consists essentially of a 68 c.c. four-stroke petrol engine with an extended crankshaft which carries the generator armature. As the engine is fitted with coil ignition, a secondary battery is necessary and 12V, 22 Ah lead-acid batteries were therefore obtained from the same source as the generating sets. This type of battery is contained in a wooden case with a hinged lid and carrying strap, the output being terminated on a two-pin, non-reversible, weatherproof socket.

A combined clip and stand lamp was developed for general use in underground plant, and 40W traction type lamps used because of their more robust construction.

The complete equipment is illustrated in Fig. 1.

Experience with Generating Sets in Service.

Distribution of the war-surplus equipment commenced in 1947 and it has proved extremely popular with external staff as a result of the great improvement experienced in working conditions in manholes.

However, with the introduction of these sets, maintenance difficulties also began to arise as many sets were found to be damaged or incomplete on receipt, and the small stock of spares, which could not be replaced, was quickly dissipated in making them serviceable. Many of the batteries were also found to be unserviceable from the effects of prolonged storage or damage sustained in transit.

Day-to-day maintenance of generating sets and batteries is carried out by the external staff using the equipment, but larger overhauls and repairs are handled by Motor Transport staff who have been obliged to exercise much ingenuity in order to overcome the shortage of spares.

Design of Replacement Generating Sets.

In 1948, the design of a generating set to supplement and ultimately replace the war-surplus equipment came under consideration.

The following features appeared to be desirable :—

(*a*) The voltage should be retained at 24V to facilitate interchangeability with the existing equipment but the output should be increased to 500W to allow for

† The authors are, respectively, Executive Engineer and Assistant Engineer, External Plant and Protection Branch, Engineer-in-Chief's Office.

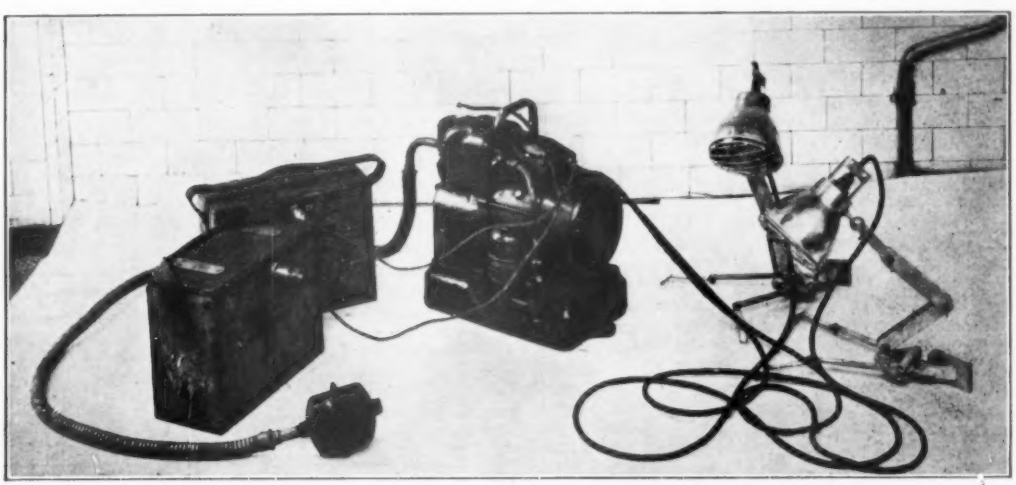


FIG. 1.—COMPLETE EQUIPMENT USING WAR SURPLUS CHARGING SET AND BATTERIES.

operation of various other items of equipment at present under consideration.

(*b*) The weight should not greatly exceed that of the war-surplus set (93 lb.).

(*c*) The set should be of unit construction for lightness and compactness.

(*d*) The set should be simple to operate and voltage regulation should be automatic.

(*e*) The set should be operated in conjunction with a 24V battery. This is necessary because it is undesirable from the noise aspect to run the engine at night when shift work is being carried out in a residential area; also, the provision of a battery saves unnecessary wear and tear on the engine since the set may be shut down when light loads are connected and started up only when it is necessary to recharge the battery.

(*f*) A four-stroke engine should be employed. Two-stroke engines are not favoured because of (i) noise and (ii) the lubrication system relies on mixing oil with the petrol, a requirement which is apt to be overlooked by the operator, with consequent damage to the engine and increased major maintenance.

(*g*) It should be possible to supply a load from the generator whilst battery charging is in progress.

(*h*) The ignition should be switched off automatically when the battery voltage reaches a predetermined figure in order to avoid unnecessary engine wear.

In the production form of the generator set, known in the Post Office as "Generator, P.E.D., Portable," unit construction was found to be too expensive, and standard commercial engine and generator units had to be employed with inevitable increase in weight

Description of Generator, P.E.D., Portable.

Illustrations of the new generator set appear in Fig. **2**. The engine drives the generator through a flexible coupling and both units are mounted on a bed-plate fabricated from sheet steel.

A control panel is mounted on the guard frame over the generator with the output of the generator terminated on five 2-pin non-reversible weatherproof sockets connected in parallel and mounted on the front of the control panel. At the back of the panel are housed the combined voltage regulator and cut-out unit and the voltage sensitive relay, a lid protecting these units from dirt and water.

Also mounted on the control panel are a moving coil ammeter reading 0 to 30 amps., and a 25 amps. slydlock fuse, both of which are connected in the generator circuit. The starter and voltage sensitive relay reset buttons are mounted on top of the control box for convenience in operation.

A petrol tank, having a capacity of one gallon (sufficient for 5 to 6 hours' running on full load) is mounted on the guard frame as shown in the illustrations.

Engine. The engine, a single-cylinder four-stroke air-cooled unit, develops 1·3 b.h.p. at 3,000 r.p.m., and is maintained at this speed by a centrifugal governor enclosed in the crankcase. The governor operates the throttle butterfly valve by means of an external linkage and provision is made for the speed of the engine to be varied within small limits by adjustment of a tension spring attached to the linkage.

A fan is attached to the flywheel, air being directed over the cylinder by a cowling to cool the engine. Flywheel-magneto ignition is employed, which makes it possible for the set to be operated without batteries if necessary, and the ignition system is fully screened to avoid interference with radio reception. A pulley fitted on the end of the crankshaft remote from the generator enables hand starting to be effected by a rope in the event of the battery charge being so low that it will not motor the generator. The engine is fitted with two controls only—the choke, which consists of a shutter on the air intake filter, and the magneto cut-out button.

Generator. The generator is a two-pole shunt wound machine, fan-cooled and of drip-proof type with grease-packed ball bearings. The armature conductors are wound in semi-enclosed slots, the slot insulation being glass fibre, and an auxiliary field winding is provided to enable the machine to be motored from the battery when starting.

Automatic Voltage Regulator. A combined cut-out and voltage regulator unit is fitted. The cut-out is provided with shunt and series windings and is adjusted so that the points close when the generator voltage reaches 24·5V, thus completing the circuit between generator and load. The series coil is connected to assist the shunt winding under these conditions. If a battery is connected, however, and the generator voltage falls below the battery voltage, a reverse current will flow. The magnetic field of the series winding then opposes that due to the shunt winding, causes the armature to release, opens the cut-out points and thereby prevents the battery from discharging through the generator. Release occurs when the reverse current is between 3 and 4 amps.

The voltage regulator electro-magnet also carries shunt and series windings. As the generator voltage rises, the magnetic effect of the shunt winding increases until the armature operates and the moving contact C1 (see Fig. **3**), which is normally held against the fixed contact A, moves

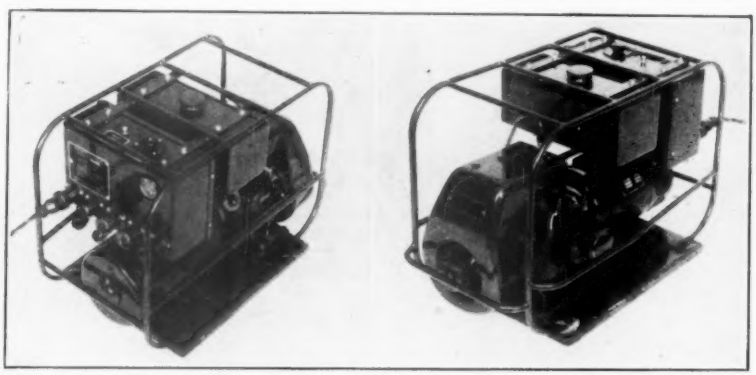


FIG. 2.—TWO VIEWS OF A GENERATOR, P.E.D., PORTABLE.

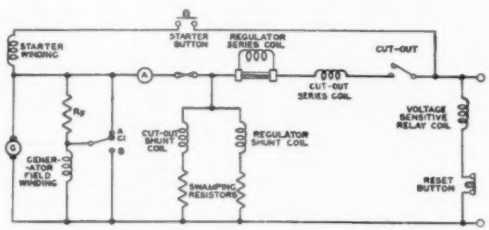


FIG. 3.—CIRCUIT DIAGRAM OF GENERATOR, P.E.D., PORTABLE.

to its mid-position thus removing the short-circuit on the series field resistor, R_F. The generator field is weakened therefore and the generated voltage reduced. Under this condition the pull of the shunt coil also diminishes and the armature of the voltage regulator therefore restores to normal. Contact C1 then makes again with the fixed contact A, thus short-circuiting the field resistor, R_F, and strengthening the generator field, and the generator output voltage is thus held substantially constant as the generator speed increases. Ultimately a speed is reached at which the required output voltage is generated with the resistor R_F permanently in circuit. Above this speed the contact C1 makes with the fixed contact B, short-circuits the generator field windings and connects the resistor R_F across the generator armature thus almost completely destroying the excitation. The moving contact continues to alternate between its mid-position and the fixed contact B until, if the speed were increased to a value above the normal operating range, a point would be reached at which the required voltage would be generated solely due to the residual magnetism of the machine. The series turns aid those of the shunt winding and by arranging for the former to carry a proportion of the load current, a compensated voltage characteristic is obtained. The heavier the load current, the lower is the voltage at which regulation occurs, thereby ensuring that the generator is not overloaded, and limiting the initial current when a completely discharged battery is connected in circuit.

Output Characteristics.

The compensated voltage characteristic is illustrated by the curves in Fig. **4**, which were plotted from the results of

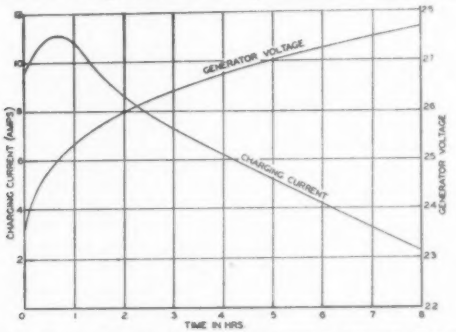


FIG. 4.—VARIATION OF GENERATOR OUTPUT DURING BATTERY CHARGING.

tests on the prototype generating set. The generator was connected to a 54Ah 24V battery which had been discharged to 1V per cell. In spite of the discharged state of the battery the initial charging current did not exceed 11 amps., the generator voltage being regulated to approximately 23V. As the battery terminal voltage rose on charge, the regulator allowed the generator voltage to increase at a somewhat slower rate, giving a battery charging current which gradually tailed off as shown.

At hourly intervals a resistive load was switched in circuit and the division of generator current between load and battery measured. These results are plotted in Fig. **5**. The battery charge continued until the point was reached where the battery voltage equalled the generator voltage when a load was being taken from the set. From that point onwards, the battery commenced to take an increasing share of the load. The heavier the resistive load, the lower was

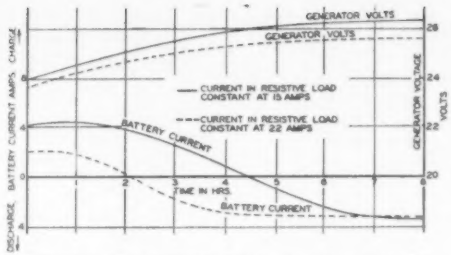


FIG. 5.—EFFECT OF RESISTIVE LOADS ON GENERATOR VOLTAGE AND BATTERY CHARGE AND DISCHARGE CURRENTS.

the generator voltage and the lower the voltage at which the battery commenced to discharge.

The dual requirements of battery charging and operation of other equipment are conflicting since the former demands varying voltage characteristic whilst the latter requires that the voltage should remain as steady as possible. The compensated voltage control provides a compromise. Excessive charging currents are avoided and the output voltage variations are restricted to a reasonable amount, at the expense of a certain proportion of the battery capacity since the charge is stopped before gassing commences.

Electrical Circuit.

A voltage-sensitive relay, which may be adjusted to operate within the range 28-31V, is connected across the circuit on the battery side of the cut-out. The contacts are normally open, but when the battery voltage reaches the relay setting the relay operates and its contacts short-circuit the magneto contact-breaker points, thus stopping the engine. The relay will not restore to normal until the voltage applied to the coil falls to a low value. It is desirable, however, to be able to restart the set at any battery voltage, and a reset button is provided, therefore, to trip the relay by breaking the coil circuit.

Batteries.

A 24V 40Ah battery, with the Post Office title of "Battery, Secondary, Portable, No. 14," which is suitable for use with both Generators, P.E.D., Portable and the original generating sets has been produced in conjunction with the Telephone Development and Maintenance Branch of the Engineer-in-Chief's Office. The battery is contained in a reinforced hardwood case with a hinged lid, and the output is terminated on a 5 amp., non-reversible 2-pin weatherproof socket accessible from the outside of the box.

Future Developments.

250 Generators, P.E.D., Portable are now in course of delivery, but as there was insufficient time to carry out extensive field trials before a large number of the original sets required replacement, further modifications may be made to the specification as the result of experience gained with the new sets.

Consideration is also being given to the design of accessories for use with the generating sets, including a 500W portable cable drier, and an electric soldering iron.

Acknowledgments.

Acknowledgments are due to officers of the Power, Motor Transport and Test and Inspection Branches of the Engineering Department for their constructive criticism and advice which proved most helpful during the development of the set, and to the L.T.R. Engineering Branch and City Area for co-operation in arranging trials.

Introduction to Electronic Exchanges—Trunking and Selection Systems

T. H. FLOWERS, M.B.E., B.Sc.(Eng.), M.I.E.E.†

U.D.C. 621.395.34

In a general analysis covering all forms of trunking and selection the author re-evaluates the basic principles of automatic telephony and then shows how these principles can be applied to electronic exchanges.

General.

WHEN the study of the possibilities of applying electronic switching techniques to automatic exchanges was first commenced, the question which naturally arose was whether the basic principles of known exchanges would necessarily apply to electronic exchanges. It seemed very likely that this would be the case. Certainly an electronic analogue of every electro-mechanical switching device can be produced, so that partially or fully electronic exchanges which are analogues of the existing exchanges in their various forms are possible. The analogues are not, however, exactly equivalent, notably in cost, reliability and speed of operation ; existing exchange systems are solutions to a highly complex problem, and the solutions no longer apply when the characteristics of the apparatus on which they are based is changed. Moreover, to have proceeded by way of analogues would have neglected the possibility, which is shown in this article to exist, of an electronic exchange for which there is no electro-mechanical analogue. Hence, there was a need for a re-examination of the basic principles of automatic telephony. An outline of this process is one of the objects of these articles. In the first article[1] it was shown that a speech path switch of any size can be built up from element switches which, in turn, may be constructed from any means of making and breaking a speech channel. In automatic exchanges, except those of the smallest size, it is uneconomic for element switches to be built up into one switch large enough for the whole exchange. The use of a number of smaller switches to achieve the result of one large switch is the main subject of this article.

Problems and Definitions.

The general problem of a telephone network of any size can be reduced to that of the single exchange which is connected by junction circuits to at least one other exchange and connected by what will be termed terminal circuits to subscribers' stations, manual board jacks and a variety of other services. A terminal circuit which starts a call is said to call, or be a calling circuit ; a calling terminal circuit indicates by dialling or other signals, which are termed called number signals, that connection is required to another terminal circuit which is then termed a called circuit. If the called circuit is on the same exchange as the calling circuit, the connection can be completed in that exchange. If the called circuit is not on the same exchange as the calling circuit, the calling circuit is connected to a junction circuit in the line of advance of the call, the junction circuit being a called circuit at the first exchange and a calling circuit at the next exchange. A calling junction circuit indicates, again by called number signals, that connection is required to a terminal circuit, and the whole process is repeated (that is, connection of a calling circuit to a called terminal or called junction circuit) until the required connection is completed.

From the description so far given there does not appear to be much difference, from an exchange switching point of view, between a junction and a terminal circuit and many of the distinctions commonly drawn are arbitrary. Subscribers' circuits generally, but not invariably, have to be operated bothway, that is, as both calling and called circuits ; junction circuits, generally, but not invariably, are worked unidirectionally. Analytically, there is every reason to regard bothway working as the general case for all circuits and unidirectional working as the special case. Again, junctions are generally heavily-loaded circuits provided in groups of more than one line, and subscribers' circuits relatively lightly-loaded single circuits or P.B.X. groups ; but the switching system must be capable of accommodating junction circuit groups down to one circuit and subscribers' circuit groups of any number of circuits from one upwards, and the most heavily loaded P.B.X. circuits carry more traffic than the least heavily loaded junction circuits. In this article, the possibility of any essential difference between the various groups of circuits connected to an exchange will be neglected. An exchange is regarded as a switch to which groups of circuits are connected, the groups varying in size from one circuit upwards, the switch providing the possibility of bothway working for each circuit and having the function that, in response to called number signals from a calling circuit, it makes or attempts to make a connection between the calling circuit and a free circuit in a called group of circuits designated by the called number signals.

The traffic which an exchange is required to handle is never known with precision in all its aspects. For example, the calling traffic originated by individual groups of subscribers' circuits is in general known only very roughly from the meter readings and ticket records on which the charges are based, and the traffic received by individual groups of subscribers' circuits is in general known even more approximately from the assumption that it is equal to the calling traffic. The effects of defective knowledge of the traffic and unexpected variations in the traffic can be minimised, as is well known, by utilising simple principles based on probability theory. Briefly, this means keeping the traffic in the largest blocks possible, the traffic in each block being derived from as many independent sources as possible. The economy of, and service given by, an exchange are largely dependent on the extent to which these principles can be carried out.

The trunking problem arises because, for practical and economical reasons, it is necessary to build exchange switches up from smaller switches assembled in ranks and connected in series by trunks between the ranks. Circuits between ranks of switches will be referred to as trunks, the term "circuit" being reserved for terminal and junction circuits. Trunking is concerned with the number and arrangement of the circuits, switches and trunks to form an exchange which will carry the traffic offered at the least cost and with the best service to the users. The selecting system is concerned with individual connections as demanded by calling circuits. The trunking and selecting systems are not, however, independent of one another. The selection system usually depends on a particular system of trunking which may reflect on the amount of plant needed ; the selection system may also not be capable of utilising to its maximum capacity, the plant provided, a fact which again reflects on the amount of plant needed.

† Staff Engineer, Research Station.

P.O.E.E.J., Vol. 43, p. 61.

Trunking Systems

For manufacturing reasons, groups of element switches are made up into unit switches in the factory. In Strowger systems the unit switch is usually ten 2-motion switches made up into a shelf, and in the Bell cross-bar system the cross-bar switch is a unit of either 10 × 10 or 10 × 20 contact assemblies, a number of which are made up into a still larger unit called a frame. For each exchange a number of unit switches are installed, connected together, and interconnected by trunks to form a switch of the requisite size. The processes involved will be generalised with the aid of the following symbols.

Symbols.

Trunking diagrams are usually drawn in symbols which are related to particular kinds of switches. To appreciate the basic principles, a set of symbols is required to generalise all types of switches. In this article the symbols in Fig. **1** will be used. The plain rectangle of Fig. **1** (*a*) is the general symbol for a switch of any kind. It is understood that there are circuits connected to the left-hand side, and other circuits connected to the right-hand side, and the switch can connect each circuit on one side to at least some of the circuits on the other side. The symbol itself conveys no idea of the size of the switch ; for example, the effect of multipling or otherwise associating two switches together is to produce a larger switch. The two switches may each be represented by a rectangle or a single rectangle may represent both switches, depending on whether it is desired to treat them as two separate switches or one larger switch. Hence the rectangle symbol may represent any size of switch from an element-switch to a complete exchange. Fig. **1** (*b*), (*c*) and (*d*) represent switches having some specified characteristic, but again not conveying the size of the switch. Thus, (*b*) represents a full-availability switch of any sort in which any one of N circuits connected on one side of the switch may be connected to any one of M circuits on the other side, the number of simultaneous connections being limited only by N or M, whichever is the less. The symbol may thus represent, among others, a single Strowger switch, or a shelf of multipled Strowger switches, or a cross-bar switch. If, due to the characteristics of a switch, a circuit on one side of it cannot be connected to a circuit on the other side, even though the circuit on the other side is free, the switch is said to be a limited availability switch. Limited availability takes two forms. In one form, the switch is not able under any circumstances to connect some of the circuits connected on one side of it to some of the circuits connected on the other side. For example, in a Strowger exchange, a number of 2-motion switches are usually formed into a rank with their bank contacts connected in graded multiples, and each circuit connected to a set of wipers can be connected by the wipers to only a limited number of circuits in each grading. This form of limited availability switch is indicated, as in (*c*), by a dot placed inside the rectangle which represents the switch.

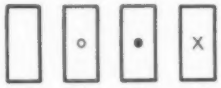


Fig. 1.—Switch Symbols.

The second form of limited availability is inherent in any useful arrangement of switches connected in ranks in series. It is illustrated in a very simple form in Fig. **2**. Three unit switches on the left each have one trunk connecting them to each of the three unit switches on the right. Each switch on the left has circuits connected on its left side and each switch on the right circuits connected on its right side. Treating the whole assembly as a single switch, it can be seen that any circuit on the outside left may be connected to any circuit on the outside right, but only if the trunk between the switches concerned is not already engaged on another connection. If the whole assembly of Fig. **2** is treated as a trunking unit, it is represented by the symbol of Fig. **1** (*d*). This method of forming self-contained units from smaller switches is common in systems which employ small capacity switches, cross-bar switches or 10-point uniselectors for example. A unit is usually made up of two ranks of the small switches, with a uniform cross-net of trunks between the ranks and one hundred or more circuits connected on each of the two sides of a unit. The size of the switch thus produced is more convenient as a trunking unit than the smaller switches from which it is formed.

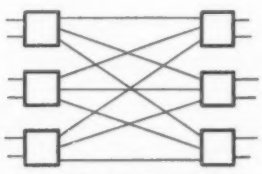


Fig. 2.—Two Ranks of Switches in Series.

In addition to the symbols for switches, it is useful to have symbols for the connection of groups of circuits to the switches and for the trunking between switches. In Fig. **3** (*a*)

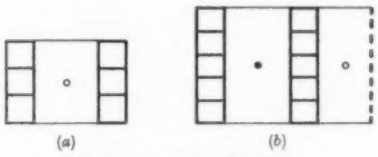


Fig. 3.—Trunking Symbols.

two ranks, each of three switches, are connected by a network of trunks represented by the straight lines connecting the extremities of the two ranks, the network having the characteristic, denoted by the circle placed between the two straight lines, that there is at least one trunk from each switch in one rank to each switch in the other rank. This form of network is said to be a full network. A full network between the ranks may not, however, be desirable ; if the number of switches in one rank exceeds the number of trunks connected to each switch in the other rank, a full network is not possible. A network of trunks which does not provide a trunk between each switch in one rank and every switch in the next rank is a limited network and denoted by a dot as shown in Fig. **3** (*b*). To the right is also shown another symbol, a dashed line, which represents a block of groups of circuits connected to a rank of switches. The circle conveys that every switch in the rank has connected to it at least one circuit in each group of circuits ; a dot instead of the circle would mean that not every switch had connected to it at least one circuit in each group of circuits.

General Solution.

Fig. **4** represents in the symbols just described the general solution to the problem of an exchange which will interconnect, by means of ranks of switches in series, the circuits connected to it. Bothway circuits are connected to two points on the exchange. A calling circuit calls on the left connection and communicates called number signals to the exchange, which then finds a path from left to right through the exchange to a free circuit in the designated group of circuits. If no such path exists other action is taken but is here neglected. The transmission and reception of signals and the finding of free paths will also be neglected for the time being, and attention concentrated on the provision and arrangement of switches

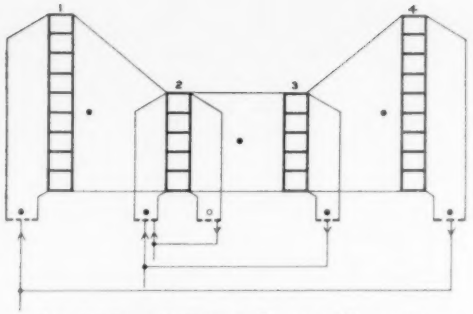


FIG. 4.—GENERAL FORM OF EXCHANGE TRUNKING.

and trunks between them so that free paths can exist often enough to satisfy the grade of service demanded.

The number of ranks of switches will vary according to a number of factors. Four ranks of switches are shown in Fig. **4** and numbered **1** to **4**. Selection starts from rank **2** to which large groups of circuits are directly connected for their calling traffic. Small groups of circuits are connected to rank **1** which concentrates the calling traffic from these circuits to a smaller number of trunks connected to rank **2**. Between ranks **1** and **2** is a limited network which provides trunks between ranks **1** and **2** sufficient to satisfy the appropriate grade of service. Calls start their selection operations from the circuits and trunks connected to the left of rank **2**. Rank **2** is connected to rank **3**, and rank **3** to rank **4**, each by a limited network adequate to the traffic.

Selection starts at some time or other from every circuit and trunk connected to the left side of rank **2**. A circuit or trunk has access only to the trunks on the right hand side of the switch to which it is connected, and this switch has access to only a limited number of switches in rank **3** and so on. However, it will be clear that, provided each switch in one rank has access to at least two switches in the next rank, and there are enough ranks of switches, a number of paths will exist from every circuit and trunk on the left of rank **2** to even a single circuit on a later rank, and that the availability of a group of circuits to a calling circuit is dependent *inter alia* on the size of the group, the rank of switches to which it is connected and the distribution of the circuits over the switches of that rank. Groups of circuits are thus connected for their called traffic to the earliest rank which gives them enough availability from the calling side of rank **2** to satisfy the grade of service. Of a group of circuits connected to the called side of the first rank of selectors (rank **2** in Fig. **4**) some must be available to all the switches in that rank, but this is not necessary in later ranks or possible for small groups.

Particular Solutions.

A number of particular cases of the general solution which has just been described will now be discussed. The most important of these is the one which has (*a*) the trunks between ranks arranged in networks which follow as regular a pattern as is possible with the trunks from one switch spread over as many switches in the next rank as possible ; (*b*) the circuits of each group distributed on both the calling and called sides as evenly as possible over as many switches as possible of the rank to which they are connected ; (*c*) circuits connected on the calling and the called sides of the switches in the ranks so that the traffic is evenly distributed over the switches according to the best available data on calling and called traffic. This solution results in the minimum of switches of a given size and the minimum number of trunks between switches and, by minimising the effects of deficient traffic data and unexpected overloads, gives the best service to the subscribers. Other factors affect the total cost and practicability of this particular solution ; although very nearly all existing telephone switching systems use this solution on the calling side, none does so fully on the called side.

The trunking system usually adopted in practice differs from that just described in two respects. First, on the called sides of the switches the circuits are connected as groups each to one switch and not distributed over the switches in the rank to which they are connected. The traffic per switch is still distributed according to the best available traffic data so that each switch in a rank is as equally loaded as possible, but the distribution cannot be so uniform or the overload on a group spread so much as in the first particular solution described. Secondly, the networks of trunks between the ranks of switches are divided into groups each sufficient to carry the expected traffic to a discrete section of the switches in the higher rank of switches. The system is illustrated in Fig. **5** for systems

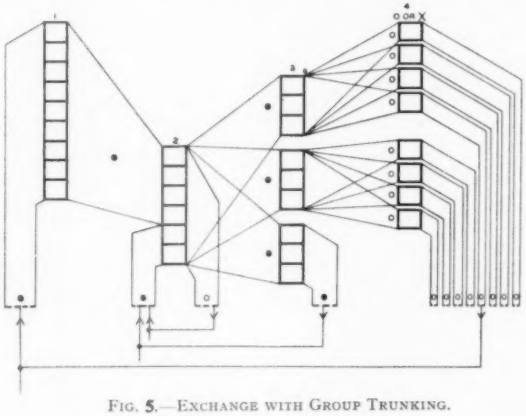


FIG. 5.—EXCHANGE WITH GROUP TRUNKING.

which use full availability switches to Fig. **1** (*b*) or limited availability switches to Fig. **1** (*d*), and in Fig. **6** for systems

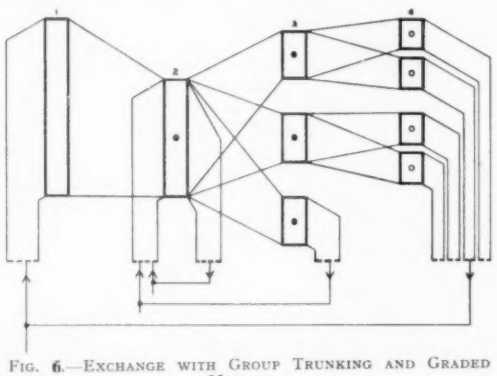


FIG. 6.—EXCHANGE WITH GROUP TRUNKING AND GRADED MULTIPLE.

which use graded multiple types of limited availability switches for all ranks of selectors except the last, which must be composed of full availability switches (or switches to Fig. **1** (*d*)).

In addition to its better traffic distribution, the first-described particular solution has a further considerable advantage over those of Figs. **5** and **6** in the allowance which has to be made for growth of the groups of circuits. Since, in the last two cases, the circuits are connected as groups, space has to be allowed at each switch for the growth of each group which is likely to increase in size, notably P.B.X. groups. The total space which is thus provided is inevitably greater than that which will eventually be taken up. With the first arrangement on the other hand, since any circuit can be connected anywhere in its appropriate rank, the space left for growth can be much more nearly equal to the eventual requirements.

A development of Fig. **4** which can, and usually does, result in still further economy in switches is shown symbolically in Fig. **7**. Circuits there have only one point of

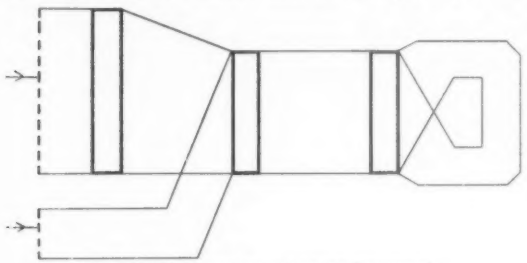


FIG. 7.—EXCHANGE WITH LOOPED TRUNKING.

connection to the exchange switches. The bothway feature is provided by a loop path within the exchange. With this arrangement most, if not all, the ranks of switches and networks of trunks between the switches have to carry bothway traffic. The economy of the arrangement arises from the assembly of the traffic into blocks made up of both calling and called traffic.

SELECTION SYSTEMS

Selection can be reduced to sequences of the following basic operations :

(*a*) A signal, called a mark, which defines the circuit or trunk from which selection starts.

(*b*) A signal (or signals) which defines the connection to be made.

(*c*) The marking of a free trunk or circuit in a group of trunks or circuits, any one of which when connected to the trunk or circuit defined in (*a*) will satisfy the condition (*b*).

(*d*) The control of a switch to make the connection between the circuit or trunk defined in (*a*) to the trunk or circuit defined in (*c*).

These operations can perhaps be best explained by reference first to the familiar Strowger system of selection, and to Fig. **6**. Calls from circuits connected to rank **1** will be neglected for the time being, and selection considered to start from rank **2**. A calling circuit connected to a selector in rank **2** defines itself as the circuit from which selection is to start by looping the line to give a calling signal. Called number signals which define the connection to be made are then received in the form of trains of dialling impulses. All the trains taken together define a circuit in a group of circuits connected, say, to rank **4**, a free circuit of which is to be connected to the calling circuit. In the Strowger system, this is accomplished not directly, but in stages. The group trunking and the connection of groups of circuits as groups each to one switch is chosen so that each stage is defined by one train of impulses. The trunks connected to the called side of rank **2** are divided into a maximum of ten groups. Each first selector has access to a maximum of, say, ten trunks in each group. Each selector has ten levels, each of ten contacts in a marking, i.e., P bank, one contact for each of the circuits, and one level for each of the groups of circuits to which the selector has access. For each impulse of the first digit the wipers of the first selector are raised one level. At the end of the train the P-wipers are standing at the entrance to a level of marking contacts associated with ten trunks, any one of which is suitable for connection to the calling trunk. The free circuits are marked on their marking contacts. The wipers are rotated, the P-wiper testing the marking contacts, until a contact which is marked free is reached, when the wiper rotation is stopped. The position of the wipers marks a trunk according to basic operation (*c*). Basic operation (*d*), viz., the control of a switch to make the connection, has in fact been partly completed during operation (*c*). The line wipers, which are disconnected at this stage from the calling trunk, are already in contact with the marked trunk, which is connected to the line bank contacts. Completion of operation (*d*) merely requires the line wipers to be connected to the calling trunk (H relay operation). The connection thus made through rank **2** is extended to rank **3** to define the trunk from which the next selection is to start, the next train of impulses is received and so on as just described.

A circuit terminated on rank **1** is connected, on the initiation of a calling signal, through that rank to a trunk terminated on rank **2** by a series of operations which are basically the same as those described for selection through the other ranks. If rank **1** consists of uniselector line switches, one for each circuit connected to the rank, then the calling signal on any circuit defines both the circuit from which selection is to start and the connection to be made, and the uniselector acts as a one-level selector. If rank **1** consists of groups of 2-motion switch line-finders, a calling signal takes part in two sequences of basic operations, one through the common start lead to activate an allotter which selects a free line-finder, from which in the second sequence selection starts ; in the second sequence, the calling signal, by marking the line-finder bank, defines the connection which the selected line-finder is to make.

The system of selection just described has a number of advantages, which include that it is easy to follow both in principle and in maintenance operations, that each selection is independent of every other so that as many calls can proceed simultaneously as is desired, and one faulty switch has a relatively minor effect on service. It has disadvantages which include that it requires a trunking system which is not as efficient or flexible as possible, and each element switch has to be equipped with an expensive controlling element which is idle for **99** per cent. or more of its time. This last feature has prompted systems in which the element or unit switches are made as simple as possible and the bulk of the control equipment is located in common control or marker apparatus, which serves a group of switches. The additional problem in this type of system is that when the common equipment is serving one switch in the group, none of the other switches can set up calls ; the effect of faulty common equipment can, obviously, be very serious. Nevertheless, the principle has been extended to common markers which set up connections through more than one switching stage at a time, for example, through four ranks of cross-bar switches. An even greater part of the exchange is then limited to one call being set up at a time, and speed of setting-up becomes all important. In the limit, if one marker sets up all the connections through all the ranks then only one connection at a time can be in the process of setting up. In large exchanges this means less than **100** millisecs. per connection, which

is beyond the powers of economically constructed electro-mechanical equipment. Hence group trunking has been retained in order to permit the simultaneous operation of a number of markers. A fully electronic system can be made to work much faster than the existing systems and introduces the possibility, therefore, of single marker exchanges using the highly desirable trunking arrangements described as the first particular case of Fig. **4**. Marker operation requires register-senders or register-translators to receive the called number digits at a relatively slow rate and then to pass the necessary information to a marker as quickly as possible. Electronic register-translators have been described in a previous article.[2] A single marker exchange would be very dependent on the reliability of the marker and this and many other factors which are outside the scope of this article have to be considered before it can be said that single-marker exchanges are practicable and economic. The important point at this stage is that, with electronic switching selection, trunking systems hitherto impracticable can now be considered.

Application of General Principles to Electronic Exchanges

So far as the application of the general principles of trunking and selecting systems is concerned, space in this article permits only brief mention of two ways of selecting and marking one free trunk out of a number of free trunks in a group of trunks. This problem is selected for illustration as it is the only one of the four basic selection operations which presents any difficulty. The first solution is shown schematically in Fig. **8** and is based on the well-known multi-position trigger circuit. Three valves are shown with their anodes inter-connected with their grids by resistor networks. In addition, each grid circuit has connected to it, through a resistor, a terminal P. Assume first of all that all the P-terminals are at earth potential. Then it can be designed that the whole circuit will take up one of three stable positions, each corresponding to one valve being conducting on its anode circuit and the other two non-conducting. The position at any given time may be dependent mostly on chance. Each valve anode is connected to a terminal M to which is connected the marking lead of a trunk in the group to be controlled. The trunk is unmarked when its M-terminal is near the anode supply potential, and becomes marked when the associated valve conducts; the P-terminal of the same valve is connected to the trunk which, when it is free, holds the terminal at earth potential and, when it is engaged, at a negative potential. The negative potential on a P-terminal is sufficient to prevent its valve from conducting, whatever the control from the other valves. Hence the trigger can never set itself to mark an engaged trunk and, as it can mark only one trunk at a time, will always set itself to mark a free trunk, or no trunk if there is none free. When it marks a trunk which later becomes engaged, the trigger will change without any further control to mark another free circuit. The three-valve trigger shown can be extended by various means to any number, but hot-cathode valves are, of course, expensive, and the method may eventually have only academic interest.

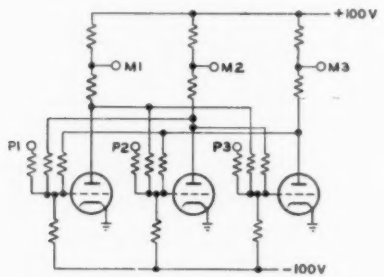


Fig. 8. Trigger Circuit Selector.

Fig. **9** also shows a similar arrangement of three valves, but the number of valves may easily be extended almost indefinitely. The valves are cold-cathode gas-discharge tubes which once fired will hold in that condition until the anode current is interrupted, or the anode-to-cathode voltage reduced below the voltage which will sustain the discharge. The common cathode resistor prevents a second tube from firing if one is already conducting. The P- and M-terminals have the same functions and operate with the same potentials as in Fig. **8**, but there is an additional control on the primers in the form of the time-spaced pulses. A tube will fire only if (*a*) there is no other tube fired, (*b*) its P-terminal is at earth potential, and (*c*) it receives a pulse from its pulse source. One form of spacing of the pulses is shown in the diagram, the pulsing in this case being continuous. Suppose that, normally, a control voltage is applied to the point C, by apparatus not shown in the diagram, to raise the cathode potentials of the tubes so that none will be conducting. If, now, the control voltage to the tubes is switched off, one tube corresponding to a free circuit will fire, the actual tube depending on the phase of the pulses at the instant of switching off the control voltage. This form of selection is analogous to selection by a non-homing uniselector. If, however, the pulses are normally absent and, after switching off the control voltage, pulses are applied to the tubes in order starting, say, from the left, the selection becomes analogous to the fixed-order testing provided by a homing uniselector.

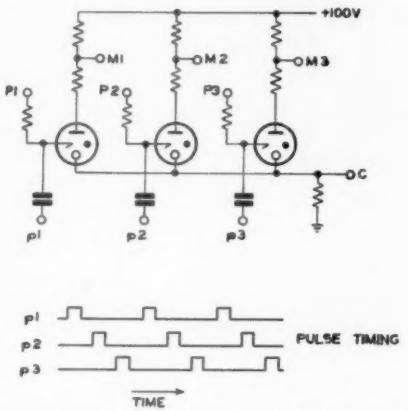


Fig. 9.—Cold-Cathode Gas-Discharge-Tube Selector.

Conclusion.

This article completes the series on the introduction to electronic exchanges. It is hoped that some of the possibilities have been made clear. There is no doubt that electronic exchanges will be produced, but how well and how soon their particular merits will enable them to compete with electro-mechanical equipment in the expanding art of switching, only the future can decide.

[2] *P.O.E.E.J.*, Vol. **43**, p. 177.

Whitehall Gardens P.A.B.X.

F. T. PERKINS†

U.D.C. 621.395.251

This article describes a recent Private Automatic Branch Exchange installation with ultimate capacity for 3,000 lines. Certain non-standard facilities have been provided to meet the requirements of the various Government Departments served by the exchange, and enquiry positions of novel design are fitted to suit the local conditions.

Introduction.

IN October 1950, the largest P.A.B.X. in the country was opened to serve various Ministries accommodated in the new block of Government offices in Whitehall Gardens, London, the exchange being situated on the ground floor of the building at its north-east end and on the Thames Embankment side. Apart from the special features of the equipment and its installation which are referred to later, interest arises from the historical associations of the site since, in Tudor times, it was occupied by the Palace of Whitehall.

During the excavations for the new building, several parts of the old Palace wall were uncovered, and it is known that the steps which originally led from the Palace to the river, together with an old riverside terrace, still lie below ground level; these will be uncovered and reconstructed in sunken gardens to be built facing the Embankment.

An interesting feature of the construction work was the moving of the Tudor wine cellar or crypt (built in Cardinal Wolsey's time), Parliament having decided that this, one of the few portions of the Palace still remaining, should be preserved as an ancient monument. The Crypt protruded over the building line on the Horse Guards Avenue side, and it was decided that it should be moved intact to a new location some 10 ft. to the west and lowered 18 ft. This could not be carried out as a direct move without an extremely complex operation. The operation was arranged, therefore, by mounting the crypt on rollers, moving it bodily on to a steel gantry, jacking down on this gantry, and then moving it back horizontally some 33 ft. to its final position.[1]

General.

Proposals for the building of the new block of Government offices were first put forward in 1912, and the whole scheme was designed by Vincent Harris, O.B.E., R.A., F.R.I.B.A., but the first World War delayed the start of construction until 1936, while the second World War caused work to be suspended in 1940. When it was decided, in 1946, once more to proceed with the scheme, provision of a suitable P.A.B.X. to serve a number of Ministries had to be considered.

As the Post Office standard P.A.B.X. has been designed to cater for a total of 1,200 extensions only, the use of this type of equipment would have involved design work to extend the ultimate capacity to the 3,000 lines required. Additionally, the standard P.A.B.X. facilities do not include the control and timing of trunk and toll calls. It was decided, therefore, that in view of the time factor, the automatic equipment should be of the standard 2,000-type, non-director, with a sleeve control auto-manual switchboard equipped similarly to a group trunk exchange. This equipment does not, however, provide many of the facilities that are standard on modern P.A.B.X.s.

The initial equipment comprises 2,200 auto. and 100 manual calling equipments, 3,000 multiple, 15 "A" positions, 14 "B" positions, 4 dummy and unequipped positions, 400 dialling, 20 auto. and 70 generator signalling tie lines and an 8-position enquiry table.

The building is designed throughout for offices and physical difficulties, due to low ceiling heights, were encountered therefore in accommodating the automatic equipment. The general heating arrangements for the building comprise a network of copper tubes concealed in the ceilings, and as this was considered to be unsuitable for apparatus rooms, floor radiators were specially installed.

The clear height under beams varies from 10 ft. 7 in. to 10 ft. 8 in., and as 10 ft. 6½ in. racks were necessary to provide the required capacity within the accommodation allocated, the overhead 1-in. twin bars securing the racks had to be sunk into the plaster in several places; moreover, normal practice of cabling over the top of the racks could not be followed and large runways had to be installed at 9 ft. 1½ in. from the floor, suspended by subsidiary girders along the gangways. The presence of these runways precluded the use of standard main battery bus-bars located in the gangways above the racks and to overcome this difficulty it was decided to use the feeder fuse board method of distribution.

The auto-manual switchboard (Fig. 1) is of a modern

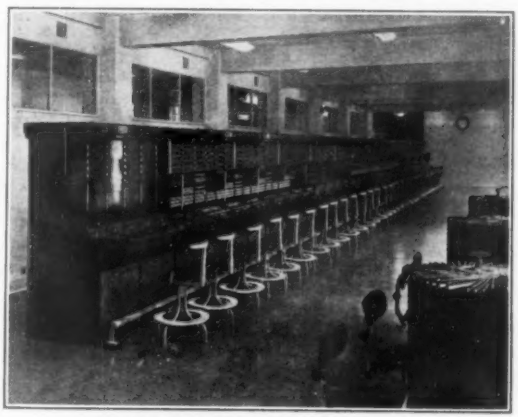


FIG. 1.—THE AUTO-MANUAL SWITCHBOARD.

design of the sleeve control type incorporating improvements such as cord fastener units, and with battery jacks located above the kicking panels and rear equipment layouts. A rear cable-shelf specially designed for the extension multiple is also included.

The "A" positions are each equipped with 14 cord circuits, 4 of which include chargeable-time clocks and handle all originating traffic on a "single-channel" basis, i.e. "0" is dialled for Assistance, Trunk or Toll calls. The "B" positions are equipped with 15 cord circuits and handle all incoming traffic including tie line "0" level circuits.

In other respects the exchange is generally similar in construction to a non-director exchange and includes separate subscribers' and equipment I.D.F.s and graded group selector racks.

† Executive Engineer, London Telecommunications Region.

[1] "Government Offices, Whitehall Gardens. The Special problem of the re-siting of an Historic Building." *Institution of Civil Engineers*, Paper No. 5765.

Facilities.

Standard circuits are used as far as possible, but departures were necessary to a degree, and it is therefore proposed to explain the facilities which are special to this exchange.

It was not considered desirable to give the exchange a name and code to allow dialling direct to extension on incoming traffic from the public network; therefore, a group of incoming exchange lines from an 11-and-over final selector unit at an adjacent public exchange was provided for each Ministry, as for any other P.B.X. These lines appear in the answering multiple of the auto-manual board at Whitehall Gardens P.A.B.X., and are lamped over the "B" positions.

A multiple of all the extensions is provided on this switchboard, with stile bar numbering similar to C.B. exchange practice, to give direct access by the operators for incoming traffic, thus avoiding dialling through the manual board selectors for each call and saving time and provision of positions. This multiple involved a relay set for each extension line and as the calling equipments are 700 less than the multiple, the relay set provision is based on the calling equipments in the interest of economy and to avoid extravagant cabling and jumpering. The multiple-access relay sets are terminated on the same connection strips as the subscribers' uniselector circuits, using 6 × 20 strips with the tags arranged for open wire straps for fault localising. This was made possible by dispensing with the usual M and M1 terminations as subscribers' meters are not fitted.

The dialling tie lines between this and other P.A.B.X.s and P.M.B.X.s could not be arranged with dialling codes from selector levels owing to the large number of groups, and it was decided, therefore, to use 2-10 and 11-and-over final selectors, according to the size of the groups, with 3-digit dialling codes. The majority of the lines are equipped for bothway working, using subscribers' uniselectors, but where line resistances are in excess of the standard for uniselector working, they are arranged on a unidirectional basis with the incoming lines connected to 1st selectors. Equipment is also provided for tie lines with resistances outside dialling limits to be worked manually using auto. or generator signalling. Facilities are available on the manual board for operators to obtain direct access in the outgoing junction multiple on most of the tie lines. Local extensions have access to all the dialling tie lines.

A group of 100 manual extensions is also provided, with facilities for manual working to and from the switchboard and connection to final selectors if automatic working is required for incoming traffic. Where automatic working is not required, N.U. tone is connected to the final selector number.

Originating calls from extensions to the London area are obtained by dialling "9" which routes the caller from the 1st selector level, via an auto-auto relay set, to a barred-trunk uniselector at the public exchange. Excess fee calls are obtained by dialling "0" and the P.A.B.X. operator extends the callers to the public exchange by full facility exchange lines which appear in the outgoing junction multiple.

Trunk and toll calls are obtained by dialling "0" and the Whitehall Gardens operators have complete control of timing as in a trunk exchange, with direct channels to London Trunk and Toll exchanges.

The numbering scheme is, 2000-2999; 6000-7999, the trunking diagram being given in Fig. 2.

Enquiry Tables.

The requirements for enquiry traffic are such that a monitor's desk as used in non-director exchanges is inadequate, drum files being necessary to contain the very large number of entries for each of the Ministries. In the absence of a suitable standard, the Engineering Department agreed to the tables being designed to suit the local conditions and two 4-position, double-sided, cordless tables are provided to accommodate up to six drum files and directory and card compartments. (See Fig. 3.)

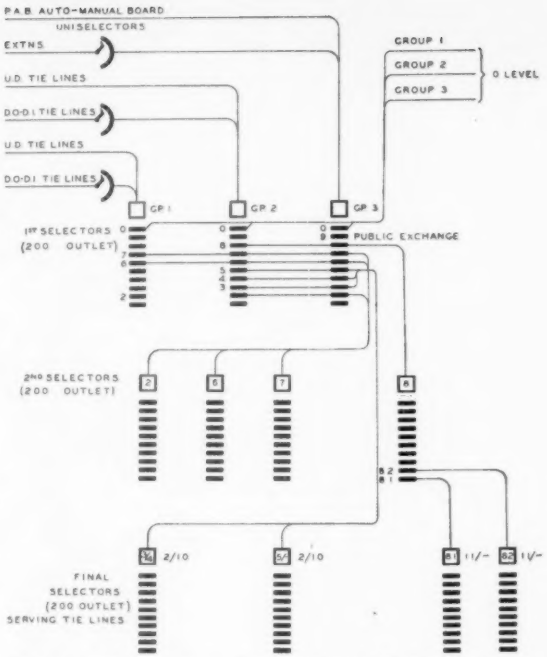


FIG. 2.—TRUNKING DIAGRAM OF WHITEHALL GARDENS P.A.B.X.

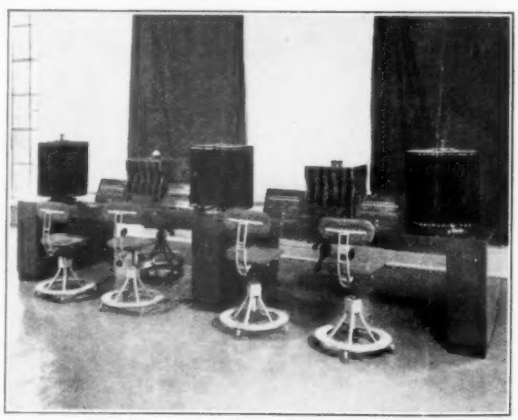


FIG. 3.—ENQUIRY TABLES WITH DRUM FILES.

Double-sided sloping panels are fitted in the centre of each table with capacity for 11 keys on each side. The circuits to and from the manual board are arranged for enquiries for each Ministry to be dealt with by separate operators and this is achieved by terminating two groups of circuits incoming from the manual board multipled on positions 1, 4, 6 and 7 and 2, 3, 5 and 8; the drum files

for each Ministry are located in a manner to suit the circuits. The arrangement also allows for concentration on position No. 1 with coupling between positions Nos. 1 and 2.

Power Plant and Distribution.

Power is supplied by two batteries of open-type lead-acid cells, each of 1,100 ampere-hour capacity, and two mercury arc rectifiers, each with an output of 50 amps. at 50 V, operating as a parallel battery automatic power plant. Space is available for the provision of a third rectifier to meet ultimate load requirements. Standard ringing and tone supplies are obtained from 75-watt inductor tone generators.

The power distribution is by twin bus-bars from the power board to the first feeder fuse board, from which the main negative feed is continued to the second feeder fuse board by two 61/·103 V.I.R. cables in parallel. The groups of racks are served by smaller V.I.R. cables from group fuses mounted on the D.F.B.s.

The feeder fuse boards (Fig. 4) are each designed to accommodate 7 group fuses and, to preserve standard arrangements as far as possible, each group is equipped with a 125 amp. regular and stand-by fuse with separate alarm lamps for each group, identical to 2000-type group fuse panels, but in this case, centralised on feeder fuse boards.

The battery positive connection is continued over all the racks by 2 in. × ½ in. copper bar laid flat and bolted to the tops of the racks thereby also serving as the earth connection for each suite of racks.

Conclusion.

The contract for the manufacture and installation of the exchange was placed in June 1948, with Standard Telephones & Cables, Ltd., the work being completed in September 1950, and the exchange brought into service on the 16th October 1950.

In conclusion, the author desires to express his thanks to Standard Telephones & Cables, Ltd., for supplying photographs of the installation.

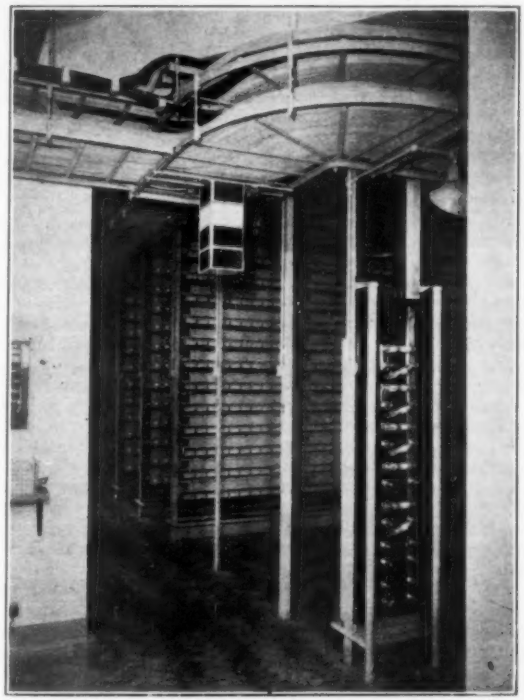


FIG. 4.—VIEW OF APPARATUS ROOM SHOWING FEEDER FUSE BOARD, CABLE RUNWAY AND RELAY SET RACKS.

Alterations to H.M.T.S. Ariel's Cable Paying-Out Gear

It has been necessary in recent years for H.M.T.S. *Ariel* to be employed in laying cables in water of depths exceeding 1,000 fathoms, and for this purpose the existing brake gear was inadequate. This gear consists of a winding drum driven from a steam engine through spur gearing. The tension on a cable during paying out operations is controlled by a brake associated with the drum, the brake consisting of an adjustable steel band which is wood-lined and water-cooled. This equipment operates satisfactorily on the type of work for which it was intended, i.e. maintenance of P.O. cables in shallow coastal waters. At the request of Submarine Branch, consideration was given to improving the design or strengthening the brake, but this was not practicable, and some form of auxiliary brake seemed the best solution to the problem.

It was ultimately decided to provide a Heenan & Froude hydraulic brake which was fitted adjacent to the winding drum and coupled to its shaft by a Morse Duplex roller chain drive immersed in oil. The basis of design was that the brake should hold a cable tension of 20 cwt. when the ship was steaming at 5 knots, under which conditions the drum shaft would be revolving at 124 r.p.m. The chain drive from this shaft to the hydraulic brake provided a speed increase of 6 to 1, i.e. 744 r.p.m., which enabled the use of a hydraulic brake of reasonable size. The size chosen was such that it is capable of holding all cable tensions likely to be experienced at all speeds above 1½ knots. Below this speed, the mechanical band brake will be used to assist the hydraulic brake and to hold the cable when the ship is stationary. It was confirmed by the manufacturers that the use of sea water from which all solid matter had been strained would be satisfactory as the brake elements are aluminium bronze and the duties light and intermittent. The space available on the ship was limited and this largely determined the type and size of equipment that could be accommodated. The brake control is extended by shafting and bevel gears to the main deck.

This new equipment has been used on cable laying operations and has proved so satisfactory that work is now in hand for providing similar auxiliary brake gear on H.M.T.S. *Iris*.

R. S. P.

The Single-Commutation Direct Current Signalling and Impulsing System

S. WELCH, M.Eng., A.M.I.E.E., and B. R. HORSFIELD, A.M.I.E.E.†

U.D.C. 621.395.34

A new D.C. signalling and dialling system is described which is suitable for use on long audio circuits. The system employs double-current signals for impulsing, incorporates features to minimise impulse distortion, and provides duplex signalling by simple means. The article covers both the general principles of the new system and its practical application to trunk working.

Introduction.

THE increasing automatisation of telephone networks is giving rise to a growing demand for dialling facilities over trunk and junction circuits, to permit the maximum economy in operating staff, and to provide a fast and efficient service for the subscriber.

On short-distance audio circuits, loop-disconnect direct current impulsing (loop dialling) may be employed. On circuits routed in multi-channel systems, the use of voice frequency A.C. signalling systems is essential. There are, however, many long audio circuits capable of carrying direct current signals, over which loop-disconnect impulsing is unsatisfactory, or impossible. It is primarily for this type of circuit that the Single-Commutation Direct Current system has been developed.

The new system gives the usual signalling and dialling facilities (including busy flash, when required), both unidirectional and bothway, on 2-wire or 4-wire audio circuits, and the duplex signalling feature of the system allows these facilities to be obtained by simple arrangements. The double current impulsing and the signal waveform improvement features of the system allow dialling with very small impulse distortion on audio circuits of length up to 100 miles of 4-wire 20 lb., or the equivalent of other types of audio circuit. The system utilises the phantom of 4-wire circuits for signalling purposes, but does not require the phantom to be extended separately to the signalling equipment.

The single-commutation system will supersede the L.D.D.C. (differentiated current) system described elsewhere[1], as it permits much simpler relay set circuit arrangements, is not so prone to false operation due to interference and no complications arise when the phantom of 4-wire circuits cannot be extended separately to the signalling equipment.

Principles of System

Duplex Signalling.

The single-commutation system is based on the balanced bridge principle as shown in Fig. **1**. *R* represents the line and r_1, r_2, r_3 and r_4 the windings of signalling relays. Series sources of signal current e_1 and e_2 complete the line loop circuit and sources e_3 (or e_4) have earth returns. The arrangement is balanced with respect to earth and resembles a Wheatstone bridge. Any circuit change across equal potential points such as A and B (or C and D), or a reversal of polarity of both e_1 and e_2 cannot affect the potential between points X and Y and hence cannot affect the earth current flowing between X and Y, although the distribution of the current between the line wires may be modified. Hence the conditions

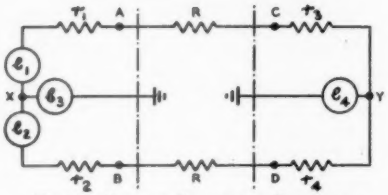


Fig. 1.—Duplex Signalling Principle.

for pure loop signalling (i.e. no change in earth current) are established.

Potential e_3 (or e_4) will produce line current of equal magnitude in each wire, flowing in the same direction. Any change in e_3 (or e_4), or a disconnection between X and Y will produce similar effect in each wire. Hence, conditions for pure earth signalling are established. Thus, loop signalling currents and earth signalling currents flow simultaneously and duplex signalling is established when these currents are detected independently.

The potential across CD, which is the algebraic sum of the voltages across the balanced series resistances r_3 and r_4, is zero for earth currents and finite for loop currents, while the algebraic differences are respectively finite and zero. The same is true of points AB and resistances r_1 and r_2. Now r_1 and r_2 are balanced windings of a line relay and r_3 and r_4 the windings of another. If the windings be connected series-aiding in a loop sense, the relay will respond only to loop currents (sum of voltages finite) and not to earth currents (sum of voltages zero). If the windings be connected in series-opposition in a loop sense, the relay will respond to earth currents (difference of voltages finite) and not to loop currents (sum of voltages zero). In this manner loop and earth current signals may be detected independently.

Fig. **2** shows the practical arrangement of the signalling and impulsing element, based on the theoretical element of Fig. **1**. The adopted arrangement uses double-current loop forward signals from the outgoing end and earth-current

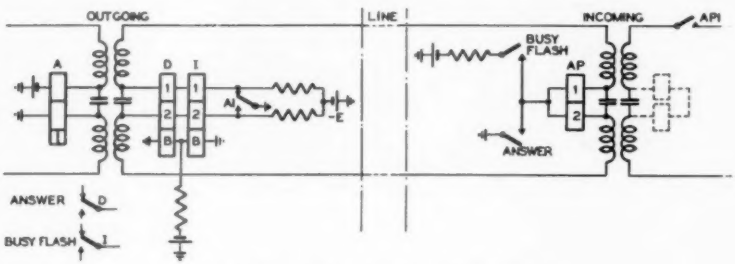


Fig. 2.—Signalling and Impulsing Elements.

backward signals from the incoming end. The double-current loop signals are obtained by the single changeover contact A1 commutating the single battery $-E$; hence the name of the system. The polarised relay AP, with balanced

† The authors are, respectively, Senior Executive Engineer, Research Station, and Executive Engineer, Telephone Development and Maintenance Branch, Engineer-in-Chief's office.

[1] *I.P.O.E.E.*, Printed Papers No. 178 and No. 184.

windings 1 and 2 connected series-aiding, operates in double-current manner to the forward loop current reversal signals transmitted by A1, but does not respond to the earth current signals transmitted back.

Relays D and I, with line windings 1 and 2 connected in series-opposition, are non-inductive and thus non-responsive to the loop currents, including impulsing, from the outgoing end, but are responsive to earth current signals from the incoming end.

An earth at the centre point of relay AP gives an earth current in one direction, to give one backward signal (say answer) and an earthed battery would give an earth current in the reverse direction to give a second backward signal (which could be busy flash if required). The D and I relays are of polarised type to (*a*) obtain adequate signalling sensitivity, and (*b*) discriminate between earth currents in opposite directions should the two backward signals be required. To detect the absence of earth current (e.g. backward clear) in addition to the presence and reversal of earth current, it is necessary to add locally-energised bias windings to the D and I relays. Earth current in one direction reinforces the bias on relay I, which does not "operate," and opposes the bias on relay D, which "operates" against its bias to give, say, the answering condition. Earth current in the reverse direction reinforces the bias on relay D, which does not operate, and opposes the bias on relay I which operates against its bias to give, say, busy flash. Relay AP is not affected by the application or cessation of earth current signals, the current being merely re-distributed between the line wires.

Normal automatic exchange switching equipment works single-current and the line impulsing system, worked double-current, must work single-current at its two ends by conversions. At the outgoing end, relay A (Fig. **2**) operates in single-current manner to the received single-current signals and at contact A1 transmits double-current signals to the system. At the incoming end, relay AP operates in double-current manner and the signals are converted to single-current by working on the make side only of contact AP1 to transmit the signals forward.

Extraneous Earth Currents.

Unwanted earth currents are a feature of earth signalling systems. These currents, which influence the operation of the D and I relays, but not AP, may arise from differences in earth potential (e.p.d.) and by potentials induced longitudinally into the line wires from 50 c/s power lines. Both these causes will be referred to as e.p.d. for the purpose of discussion ; e.p.d. can have effect only when the centre point of relay AP is earthy and this applies during backward signalling.

Assuming the loop signalling current due to potential $-E$ at the outgoing end to be flowing, and the centre point of relay AP not earthy, this point (Y, Fig. **3**) will be at

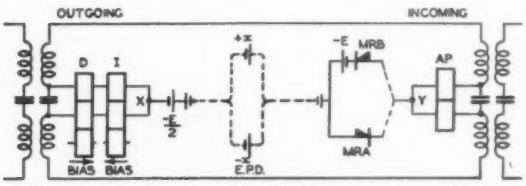


FIG. 3.—THE EFFECTS OF EARTH POTENTIAL DIFFERENCE.

potential $-E/2$ reference earth zero. If now point Y be joined via the earth to the earth (zero potential) point at the outgoing end, as would occur during backward signalling, the current in the earth path will flow from the high potential point (zero) at the outgoing end, to the low potential point Y ($-E/2$) at the incoming end. This current in the earth path may be considered as due to an assumed source of potential $-E/2$ located in the earth path, and, as far as the flow of earth current in the line (as distinct from the earth path) is concerned, point Y is at zero potential and the earth point X (Fig. **3**) at the outgoing end is at potential $-E/2$. Thus, considering the earth, but not the loop, current aspect, with point Y at zero, i.e. full earth applied, a potential of $-E/2$ can be assigned to point X. This assumption simplifies the consideration of e.p.d. effects and Fig. **3** shows the derived circuit for the earth current aspect. The resultant effect on the system of both the loop and earth currents acting simultaneously can be determined by application of the principle of superposition assuming the loop and earth currents to flow independently and using the above treatment for the earth currents.

Consider first the e.p.d. in the presence of earth applied at Y. If X is regarded as fixed and the e.p.d. as affecting Y, an e.p.d. of $-x$ volts will lower the potential of Y and reduce the potential difference between X and Y to reduce the earth current. An e.p.d. of $+x$ will raise the potential of Y and so tend to increase the potential difference between X and Y to increase the earth current. If x equals $-E/2$ (25V in a 50V system) the potential between X and Y will be zero and the earth current (and the signal) will cease. If x is greater than $-E/2$ in a negative sense, the potential of Y will be lower than that of X and the earth current will reverse in direction. This would normally give a false signal, as relay I would operate instead of D, but may be prevented by rectifier MRA connected as shown.

Similarly, in the presence of an earthed battery at Y, an e.p.d. of $-x$ will increase the potential difference between X and Y to increase the earth current, but an e.p.d. of $+x$ will reduce the potential difference between X and Y to lower the earth current. If x equals $+E/2$ (25V in a 50V system) the potential between X and Y will be zero and the earth current will cease. Again a false signal, relay D operating instead of I, due to the reversal of earth current should $+x$ exceed $E/2$, may be prevented by rectifier MRB as shown.

Induction from power lines may also cause unwanted earth currents to circulate via the wire-to-earth capacitances even when point Y is not earthy.

E.p.d.s and induced voltages, in reducing the magnitude of the earth signalling currents, reduce the signalling limit of the system.

Improvement in Received Signal Waveform.

A square wave signal may be assumed to consist of a number of sine waves of different frequencies, i.e. a fundamental and a number of harmonics. If the transmission medium, including the reception apparatus, introduces amplitude and/or phase distortion, some frequencies are distorted relative to others and the received signal is not the same shape as that transmitted.

On most types of line to which the signalling system will be applied phase distortion produces the greater effect since it delays the attainment of the steady state value to a greater degree than amplitude distortion. With phase distortion, the delay in the reception of the higher frequency components is not so great as for the lower frequency components, with the result that the attainment of steady state is spread over a longer period of time.

It was desired that, with a minimum signal of 20 milliseconds duration, the impulse distortion should be as small as possible on lines of microfarad-ohm value (CRl^2) of up to 75,000 (more conveniently expressed as line time-

constant $T = 75$ milliseconds) which represents 100 miles of 20 lb. 4-wire P.C.Q.T. Waveform A in Fig. 4 shows the

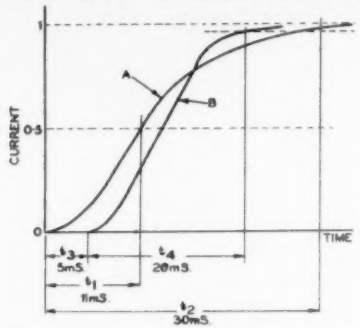


FIG. 4.—RECEIVED SIGNAL WAVEFORMS ON 75MS. TIME-CONSTANT LINE.

received signal build-up on a line of $T=75$ milliseconds. The current reaches substantially steady state in some 30 milliseconds (t_2) and it is clear that mutual interference between the build-up and decay waveforms will arise with a 20 millisecond signal and impulse distortion will result. It is necessary, therefore, to improve the received waveform by reducing the build-up time and a phase correcting feature has been incorporated.

On the types of line to which the system will be applied the phase-angle/frequency characteristic is not linear, and the line phase angle of the received current lags on the sent volts. For the system to be free from phase distortion, it is required that the phase-angle/frequency characteristic should be linear.

If the line be terminated with a suitably designed *LC* shunt resonant circuit introducing a further lagging phase angle which increases with frequency, the phase-angle/frequency characteristic of the combined arrangement is made linear over a limited, but significant, frequency range on a line of specific time-constant, and the phase distortion is reduced.

The frequencies of importance to impulsing may be assumed to be the range 10 to 200 c/s and, while the single resonant circuit termination, as designed, gives a linear phase angle characteristic over the useful frequency range 0 to 75 c/s, this range is limited and a wider range would give further improvement. This can be obtained by the addition of a similar resonant circuit which results in a linear phase angle characteristic over the wider range 0 to 85 c/s and it was considered that phase correction over this frequency range was adequate. For convenience, a shunt resonant circuit is located at each end of the line as shown in Fig. 5, where, as it will be seen later, L and r

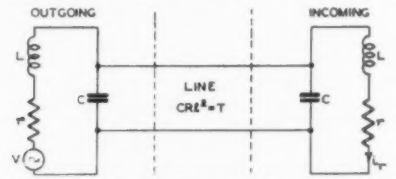


FIG. 5.—LINE TERMINATED WITH PHASE CORRECTING SHUNT RESONANT CIRCUITS.

represent the impulse receiving relay and i_r the received relay current ; V being the sent volts.

The resonant circuits are resonant at one frequency only and thus, for a fixed design, the phase correcting feature gives optimum performance at one line time-constant only. This line has been adopted as $T = 75$ milliseconds, this being the highest line time-constant over which impulse distortion is required to be a minimum and thus where correction is most required. A substantial improvement, however, is realised on lines of lesser time-constant, the improvement decreasing with T.

In the practical design the capacitance of the shunt resonant circuit is conveniently given by the 2 μF capacitors already present in the transformer type transmission bridges in the outgoing and incoming relay sets. At the incoming end the inductance of the impulse receiving relay AP completes the incoming end resonant circuit and at the outgoing end an inductor is added to give the required inductance. With C fixed at 2 μF, the inductor of the resonant circuit may be defined as 5·3 henrys with time-constant 4 milliseconds.

In addition to phase correction, the resonant circuits give an improved amplitude/frequency response over the useful frequency range compared with that of the line without terminations. For best performance the send and receive end resistances should be as small as possible during impulsing.

Waveform B in Fig. 4 shows the build-up of the received signal current in the relay AP on a line $T = 75$ milliseconds and the system incorporating the phase correcting feature. This waveform is a careful reproduction of the experimental waveform except that, for clearness of comparison, the kinks in the actual waveform produced by the E.M.F. generated by the relay when its armature moves, have been omitted. Waveform A shows the build-up of the current on the same line without the shunt resonant circuits and the considerable improvement of B compared with A will be noted. Waveform B attains substantially steady state in 20 milliseconds (t_4) compared with the 30 milliseconds (t_2) of A, the waveform is more symmetrical about the half amplitude current value and its slope is greater. All these factors contribute to reduced impulse distortion. There is a 5-millisecond delay time (t_3) before the received current waveform B begins to build up, but as this delay occurs on all signals, which may be successive impulses, it is of no consequence.

Impulsing Relay Transit Time Compensation.

The AP polarised relay transit time results in negative impulse distortion (loss of make) due to the conversion from double to single current working, and it was desired to compensate for this. The transit time of the Relay, Polarised No. 2B/106, used in the system varies with slope of signal and thus with line time-constant as shown in Fig. 6. The characteristic is not linear, but little error is

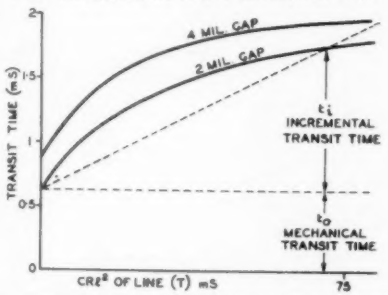


FIG. 6.—TRANSIT TIME OF RELAY, POLARISED, NO. 2B/106.

introduced if it is assumed to be so and with this assumption it can be stated that :—

$$t = t_o + t_i$$
$$= t_o + K/S$$

where t = total transit time
t_o = constant mechanical transit time
t_i = incremental transit time
S = signal wavefront slope
K = a constant.

The mechanical transit time depends upon the mechanical construction of the relay and the contact gap and cannot be reduced regardless of current amplitude and steepness of signal slope. Signals of more gradual slope will cause the transit time to increase by the incremental transit time. This increase is not linear with signal slope due to the magnetic toggle with which the relay operates.

It can be shown that a constant dis-symmetry in the operate and release current values of the relay is capable of compensating for the incremental transit time. The necessary dis-symmetry is obtained with an electrical bias by using a third winding on the AP relay, the arrangement being of bridge form. The bias affects the value of K in the transit time equation above, and for any given relay there is a value of bias which makes K zero. With this bias the repetition distortion on the relay make contact is equal to the mechanical transit time t_o; the distortion appears as shortening of the make periods of the impulses. This is true for any wavefront slope and therefore for any line. The bias adjustment is carried out as follows:—

(*a*) with no bias and no line the relay is pulsed with square wave pulses, the distortion is measured and will be equal to the mechanical transit time,

(*b*) the relay is pulsed via a network simulating a line of $T = 75$ milliseconds, and the bias adjusted to obtain the same distortion as in (*a*).

The bias adjustment is carried out on initial set-up of the incoming relay set and not on a per line basis. It is pre-set for the longest line but as the compensation given by the pre-set adjustment will vary with the signal slope, and thus line length, the output of the relay is substantially constant, and distorted by the mechanical transit time, on lines of lesser T value.

Compensation for the mechanical transit time by means of the AP relay bias would give correct compensation at one line length only. The compensation would vary with signal slope, and thus line length, and while this is a correct condition for incremental transit time compensation, it would not be correct for the mechanical transit time as this has a constant value independent of signal slope. For this reason the mechanical transit time is compensated for by the adjustment on the high speed relief relay AA in the incoming relay set, the make contact of which gives the final output from the system.

Application to a Practical Signalling System

General.

The foregoing principles have been embodied in a new D.C. dialling system for use on circuits carrying trunk traffic (Signalling System D.C. No. 2). A trunk signalling system is not required to repeat the busy flash signal and the system does not provide this facility. The new method of signalling would, however, be capable of providing this facility in a system designed for use on non-trunk circuits. Since it is not required to transmit the busy flash signal, only one earth-responsive relay is needed in the outgoing relay set and relay I (Fig. **2**) has been omitted; the battery connection to the mid-point of relay AP in the incoming relay set has also been omitted for the same reason.

The circuits are so designed that when a trunk is not in use, earth current normally flows through the line and holds the line relay (relay D) in the outgoing relay set in the position required to maintain a free condition for a testing selector or operator. This current also ensures that the line relay (relay AP) in the incoming relay set is held in its normal position. If the continuity of the line circuit is broken, the line relay in the outgoing relay set responds to the cessation of earth current and engages the circuit.

The continuity of the earth return path is broken if,

(1) the incoming relay set, or selector, is removed from the shelf jack;

(2) the incoming relay set, or selector, is undergoing a routine test;

(3) the line circuit is disconnected, as, for example, during line fault conditions,

and the outgoing relay set is caused to test engaged during the existence of any of these conditions. The continuity of the earth return circuit is also broken until the release of the incoming equipment at the end of a call is complete, and the engaged test is therefore maintained at the outgoing end until a signal (the reconnection of earth current) is received to indicate that the incoming equipment is ready for the next call; this feature is referred to as the "sequenced release" facility.

During the progress of a call over a unidirectional circuit the following signals are used:

From the Outgoing End.

Seizure and holding	Transmission of loop current in such a direction as to switch the line relay in the incoming equipment from its normal position.
Dialled Impulses	Reversals of the direction of the loop current.
Forward Release	Transmission of loop current in the opposite direction to the holding current.

When a signal is received to indicate that the incoming equipment has released, the circuit is made available for the next call.

From the Incoming End.

When the seizure signal is received, the earth current is disconnected in the incoming relay set.

Called Party Answers	The earth current is re-connected.
Called Party Clears	The earth current is disconnected.
Backward Release	When the incoming equipment has restored to normal, the earth current is re-connected.

If a battery-connected earth signal were used to indicate the answered condition, the connection of earth to one of the line conductors would switch the line relay in the incoming relay set and release the connection. When an earth-connected signal is used, the connection of a battery potential to one of the line conductors produces the same result, but since irregular earth contacts (due to working parties, etc.) are more probable than irregular contacts with the exchange battery, a greater immunity from "cut off" faults should result from the use of an earth-connected signal. As use is made of only one type of earth signal, the need to guard against false signals due to e.p.d. effects by means of rectifiers does not arise.

Impulse Correction at Tandem Switching Points.

The impulsing performance of the system offers a means of dialling over a number of links in tandem without the need for impulse correction or regeneration. To enable full advantage to be taken of this feature it is essential to minimise the impulse distortion which occurs at tandem switching points where the impulses are converted from double current signals to loop-disconnect signals and back to double current signals; this conversion, which takes place in the incoming and outgoing junction relay sets, is necessary to meet the requirements of the selectors at tandem switching points. Adjustable impulse correcting

elements have therefore been built into the relay sets. The element in the incoming relay set corrects for shortening of the "make" periods of the impulses due to the mechanical transit time of the line relay, and the element in the outgoing relay set corrects for lengthening of the "make" periods of the impulses due to the performance characteristics of the impulse repeating relay.

The greater the amount of impulse correction which it is necessary to introduce, the more sensitive the performance of the correcting elements becomes to variations in exchange battery voltage, and for this reason it is desirable to keep the amount of impulse correction to a minimum.

When a connection has been set up through a tandem switching point, the impulse repeating relay in the auto-auto relay set is controlled by the impulsing contact in the incoming relay set preceding it. Since the impulsing contact in the incoming relay set is also required to step selectors in the same exchange, it is desirable to protect this contact by providing a spark quench circuit, but, since the introduction of capacitance at this point increases the amount of correction required in the outgoing relay set, a capacitance of 0·5 μF has been used in place of the more usual value of 2 μF.

The last incoming relay set in a tandem connection repeats the impulses into the local switching equipment. The use of a 0·5 μF spark quench capacitor in the incoming relay set, instead of the 2 μF capacitor normally connected across impulsing sources, results in a slight decrease in the effective "make" periods of the impulses controlling the local selectors, which is partly compensated for by the effect of the 2 μF capacitor in the operator's position circuit on the impulse repeating relay in the outgoing relay set at the originating exchange. The compensation is not complete, however, and in any given set of local conditions the effective "make" periods of the impulses tend to be shorter than in the same set of conditions when the local equipment is controlled directly from an impulsing source provided with a 2 μF spark quench capacitor. The reduction in effective "make" period is of the order of 1 millisecond and is a characteristic feature of the present design of the system.

The outgoing auto-auto and incoming relay set circuits have been designed, as described above, to meet the impulsing requirements at tandem switching points. The impulsing performance of the outgoing sleeve control manual board relay set has been arranged to simulate that of the auto-auto relay set when seized via selector levels from a sleeve control manual board in the same building. The overall impulsing performance of the system has thus been made independent of the type of access provided at the controlling exchanges.

Outgoing Relay Set.

The practical circuit of the auto-auto relay set is shown in Fig. **7**, Relay AA and the associated components comprise the impulse correcting element which is required to reduce the duration of the "make" periods of the impulses. When contact A1 closes, an operating current flows through the operating coil of relay AA and at the same time an opposing current flows through the other coil to charge capacitor QD. The effect of the current charging capacitor QD is to delay the operation of the relay. The rectifier reduces the discharge current from the capacitor to a value which has no appreciable effect on the release timing of the relay, and the overall effect is to decrease the period for which relay AA is operated. Resistor YH provides a means of adjusting the amount of correction introduced.

The arrangement of resistors YC and YD and rectifiers MRD and MRE, in conjunction with the sending element resistors YA and YB, ensures that the values of the impedances to earth connected to the two line wires via relay D, inductor LA and the line transformer, are approximately equal irrespective of the position occupied by contact AA1. Since the windings of relay D, which is an earth-responsive relay, are astatic to loop currents, a separate inductance, LA, has been provided to assist in improving the waveform of the received signals during impulsing.

The contact of relay D is shown in the position which it normally occupies when the circuit is not in use, i.e. when an earth return current is flowing. If this current is disconnected, the contact of relay D switches to the other position and operates relay DB. If the circuit is not in use, relay DB connects an engaging condition to the P-wire, thus giving the automatic busying facility to guard against seizure during fault conditions or during testing operations. Relay DB also maintains an engaged condition during the release of the incoming equipment at the end of a call.

A similar selector level circuit incorporating battery testing elements has been produced for use in mechanised trunk exchanges.

An outgoing manual board circuit embodying the same principles has been developed for use in sleeve control exchanges. This relay set follows conventional sleeve control design principles. Seizure of the distant incoming equipment is delayed until the dial key is thrown, thus enabling a bothway circuit to be used for calls incoming to an exchange while a plug is inserted in the manual board multiple jack at that exchange. The development of an outgoing circuit for use at C.B. exchanges is at present under consideration.

Incoming Relay Set.

The practical circuit of the incoming relay set is shown in Fig. **8**. Relay AA and the associated components constitute the impulse correcting element. When the circuit is seized, relay AA is normally held operated by

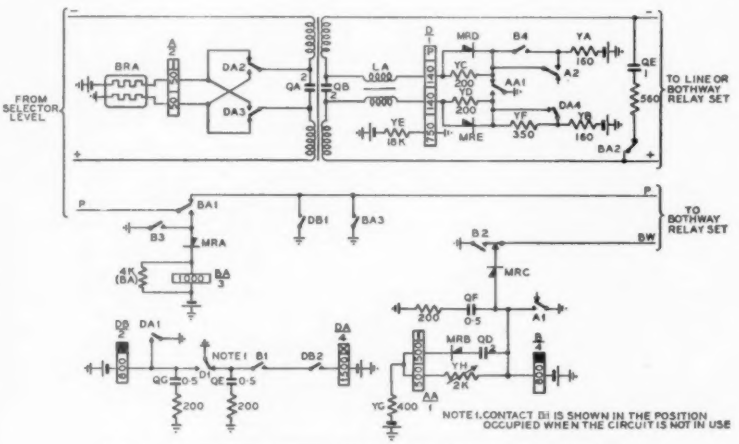


FIG. 7.—SIMPLIFIED CIRCUIT DIAGRAM OF AUTO-AUTO RELAY SET.

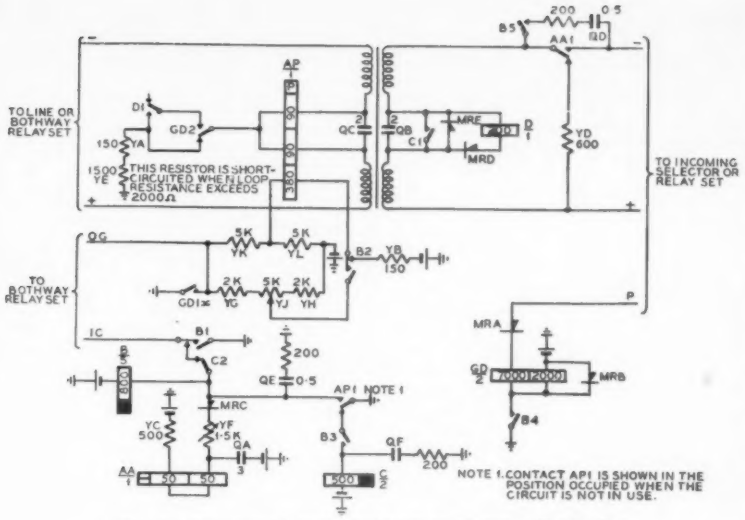

TO LINE OR BOTHWAY RELAY SET
TO INCOMING SELECTOR OR RELAY SET
THIS RESISTOR IS SHORT-CIRCUITED WHEN LOOP RESISTANCE EXCEEDS 2000Ω
TO BOTHWAY RELAY SET
NOTE 1. CONTACT AP1 IS SHOWN IN THE POSITION OCCUPIED WHEN THE CIRCUIT IS NOT IN USE.

FIG. 8.—SIMPLIFIED CIRCUIT DIAGRAM OF INCOMING RELAY SET.

contact AP1. During the "break" periods of the impulses, when contact AP1 restores to its normal position, the current through the coils of relay AA is prolonged while capacitor QA discharges, and the release of the relay is delayed. The effect is to prolong the operated period of the relay and hence to increase the duration of the "make" periods of the impulses. Resistor YF provides a means of adjusting the amount of correction introduced.

The 380 ohms winding of relay AP constitutes the bias coil. While a call is in progress, the current through the coil is derived from the network of resistors YG, YH, YJ, YK and YL, resistor YJ being adjustable to provide the necessary compensation for incremental transit time. At the conclusion of a call, during the release lag of relay GD, a larger current is passed through the bias winding of the relay to hold it in the idle position. This is required to prevent irregular operation of the relay resulting from an oscillatory discharge from capacitor QC at the conclusion of an incoming call on a bothway circuit.

Bothway Switching Circuit.

To hold the line relays in the two incoming relay sets in a bothway circuit, and to provide the sequenced release and automatic busying features, it is necessary to maintain earth currents in both directions over the line circuit. This requirement necessitates a departure from the normal practice on bothway circuits and the bothway switching equipment is so designed that each line conductor terminates in an incoming relay set at one end of the circuit and in an outgoing relay set at the other end. The method of connecting a bothway circuit is shown in Fig. **9**. Since only one line conductor is connected between each outgoing relay set and the distant incoming relay set when the circuit is not in use, it is not possible to transmit a loop signal to seize the incoming equipment. This difficulty has been overcome by arranging for a pulse of current from a positive battery at the outgoing end to be transmitted as a seizure signal. This pulse of current simulates the effect of a loop current on the line relay in the incoming relay set and seizes the incoming equipment. As soon as the incoming equipment is seized both line conductors are extended to the incoming relay set and the call proceeds in the same way as on a unidirectional circuit.

The principle of the bothway switching circuit is shown in Fig. **10**. When the outgoing relay set is taken into use an earth is connected to the BW lead and relay PB operates for a period equal to the operate lag of relay OG. The contact of relay PB transmits a pulse of positive battery current to seize the distant incoming equipment.

When an incoming call is originated, a pulse of positive battery current is received by the incoming relay set over the +wire, causing the operation of relay AP in that relay set and the immediate connection of earth over the IC lead to operate relays IC and ID. A contact of relay IC engages the outgoing circuit. All the relays involved in the seizing function are of the high speed type and the unguard period between seizure at the distant end and the engaging of the outgoing equipment at the incoming end, is reduced to a minimum. In the case of a bothway circuit terminating on a sleeve control manual board an appreciable delay may occur between the insertion of the plug in the switchboard jack and the operation of the dial key, and during this period the circuit tests free at the distant end. If the circuit is seized at the distant end during this period, the operator receives N.U. tone and is thus informed that the opportunity of using the circuit has passed.

The impedance coil, IA, reduces the amplitude of the longitudinal surge resulting from the connection of positive battery to the line conductor in place of the negative battery, during transmission of the seizing pulse, and thus minimises interference with other circuits in the same cable.

Signalling and Impulsing Performance.

The signalling limit of the system is 6,200 ohms loop line resistance representing 140 miles of 20 lb. P.C.Q.T. 4-wire (phantom). This limit is set by the earth current signalling

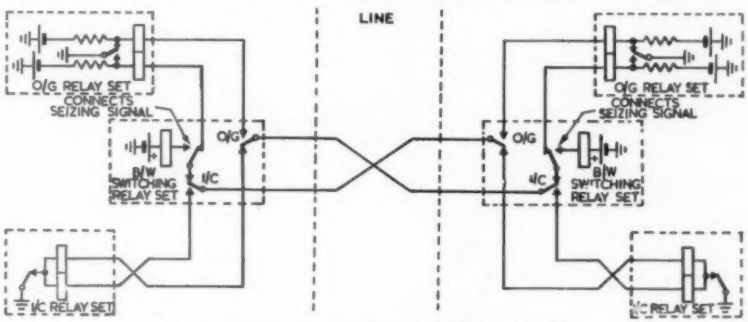


FIG. 9.—METHOD OF CONNECTING BOTHWAY CIRCUITS.

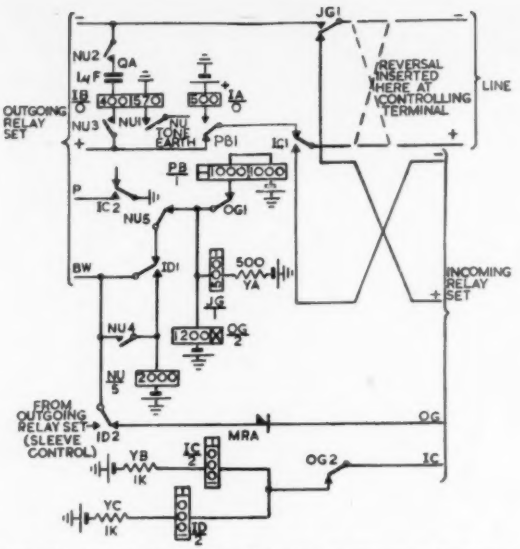


FIG. 10.—SIMPLIFIED CIRCUIT DIAGRAM OF BOTHWAY SWITCHING CIRCUIT.

and assumes 4V e.p.d. and induction from power lines assumed to be the equivalent of a further 4V e.p.d. Increase in e.p.d. above this value, which is liable to occur particularly during magnetic storm periods, will reduce the signalling limit.

Fig. **11** shows the overall impulsing performance with 50V working and a 20 millisecond signal. The distortion does not exceed 1 millisecond on lines of microfarad-ohm values (CRl^2) up to 75,000 (100 miles of 20 lb. 4-wire P.C.Q.T.). This line is less than the signalling limit of the system, but the high signalling limit permits the application of the system to the isolated cases of very long lines where the increased impulse distortion above 1 millisecond may

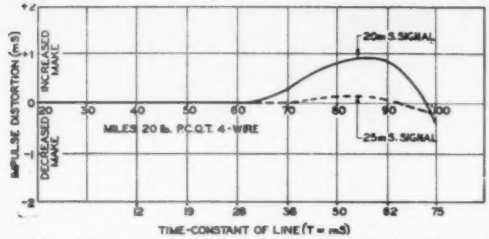


FIG. 11.—OVERALL IMPULSING PERFORMANCE (50-VOLT SYSTEM).

be tolerated. The distortion is less than that shown when the signal length is increased above 20 milliseconds.

The shunt resonant terminations are designed for correct condition on lines of microfarad-ohm value of 75,000. The increase in distortion on lines of lesser microfarad-ohm values with short signals is due to the oscillatory properties of the terminations, which, while highly damped, have not died out sufficiently to avoid mutual interference between wavefronts.

Field tests of the impulsing performance of the system on multi-link connections have confirmed the laboratory results.

Conclusion.

The Single Commutation Direct Current system is based on simple principles and provides a means of dialling with small impulse distortion over long-amplified and unamplified physical circuits. It also provides a means of dialling without regeneration over several circuits in tandem where this facility is required.

The desirability of adhering to simple arrangements has been kept in the forefront throughout the development and the application of the system should not give rise to special maintenance requirements.

Acknowledgments.

The authors wish to acknowledge the work done by past and present colleagues in the Research and Telephone Branches, who were associated with this development.

Book Review

"Telephony." Vol. 2 (Automatic Exchange Systems). J. Atkinson, A.M.I.E.E. Sir Isaac Pitman & Sons. 872 pp. 808 ill. 50s.

The very considerable task undertaken by Mr. Atkinson in preparing a completely new edition of Herbert & Procter's "Telephony" has now been successfully concluded by the publication of Volume 2, covering Automatic Exchange Systems, and this book, together with Volume 1 (General Principles and Manual Exchange Systems), makes available an up-to-date tabulated exposition of the Telephone Exchange Systems of the British Post Office, and gives an outline of switching systems used by other telephone administrations, i.e., step-by-step systems other than the B.P.O. standard, those employing marker control Uniselectors, Power Drive Systems, the Relay System, and Crossbar Switching.

The method of exposition adopted in Volume 2 is to devote the opening chapters to a broad picture of Automatic Exchange design, including the general principles of switching, traffic and trunking, switching mechanisms and apparatus racks and cabling. Six chapters then follow describing in detail the wide range of basic circuit elements used in building-up complete circuits. Those already in possession of Volume 1, in which a similar method was followed, will at once appreciate the comparative ease with which it is then possible to tackle the complex circuit arrangements found in complete switching systems.

Having thus prepared the reader, the author then covers in considerable detail the Non-Director and Director systems, Unit Automatic Exchanges, and the means of communication between Manual and Automatic Exchanges.

The concluding chapters deal with the important subjects of long-distance dialling, mechanisation of Trunk and Toll services, Private Branch Exchanges, and include an informative survey of the problems arising in the conversion of exchanges from manual to automatic working.

There can be no doubt that this authoritative volume will be regarded as the standard work on Automatic Exchange systems for many years to come, and the author is to be congratulated on the results of his labours. A striking feature of the book is the wealth of illustrations and their exceptional quality; furthermore, the page size (10 in. × 7 in.) allows close association of illustrations and relevant text, thus greatly simplifying reading and study.

The price of the book—and it is quite low compared with others of similar size and production standard—should not deter those interested in this subject from acquiring a copy of the volume, which is quite indispensable both to students and to practising telephone engineers. J. R.

The New London Radio-Telephony Terminal

C. W. SOWTON, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E., and
D. B. BALCHIN, B.Sc.(Eng.), A.M.I.E.E.†

U.D.C. 621.396.5

To cater for expansion in traffic, a new radio-telephony terminal has recently been opened with initial provision for the simultaneous control of 48 circuits. This article describes the special equipment needed for technical control and supervision of radio-telephone circuits and details that which has been provided. A broad outline of circuit operation is also included.

Introduction.

THE long-distance radio telephone service between the United Kingdom and other countries was inaugurated in 1927, with the establishment of one circuit between London and New York, since when the service has grown until, by January 1951, 41 circuits to various parts of the world were in operation. These circuits are shown in the azimuthal graticule of the world (Fig. 1) which gives the true bearing and distance of all points from London. Technical control and supervision of these circuits is provided with the aid of special apparatus at a station known as the Radio Telephony Terminal (R.T.T.) where connection is made between the radio and inland circuits. The first R.T.T., which was located at Faraday Building, London, was in service from 1929 to 1949 and, at the end of that period, provided for the simultaneous control of 13 circuits. It has now been superseded by a new R.T.T. at Brent Building, London, N.W.2, which is equipped for the simultaneous control of 48 circuits at present and has an ultimate capacity for 80 working circuits and an appropriate amount of spare equipment.

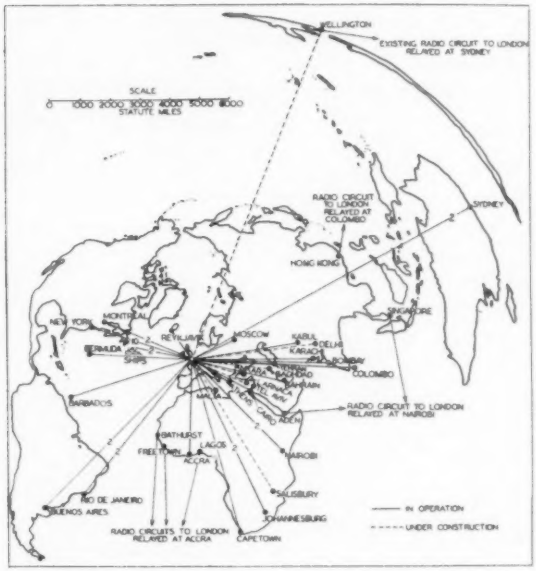


FIG. 1.—RADIO TELEPHONE CIRCUITS, JANUARY, 1951.

(ZENITHAL EQUIDISTANT PROJECTION GIVING TRUE BEARING AND DISTANCE FROM LONDON).

RADIO-TELEPHONE CIRCUITS

Before describing the Brent R.T.T. the nature of a long-distance radio telephone circuit will be considered and the necessity for the various types of apparatus required at the R.T.T. for the control of the radio circuit and for its connection to the telephone network will be examined. The radio transmitting and receiving stations in each country are well separated to prevent the signals radiated from the transmitters affecting the receivers, and both stations may be remote from the R.T.T. and the international exchange, the latter being usually situated in the metropolis. The radio stations are therefore connected by repeatered landlines to the R.T.T. and the exchange.

Fig. 2 illustrates a typical circuit between the international exchange in London and a similar exchange in a distant country. Signals over the inland telephone network arriving at the London International exchange switchboard, pass via the hybrid transformer to the transmit path of the radio terminal apparatus and continue by repeatered land line to the radio transmitting station where the audio frequency signals are translated to radio frequency and "beamed" to the distant receiving station. There they are translated back to audio frequency and pass over landlines to the distant R.T.T. and exchange. Signals from the distant exchange follow a similar but separate path between the hybrid transformers at the distant and near ends of the circuit. Different radio frequencies are used for the two directions of transmission and the "go" and "return" channels of the radio circuit constitute a "four-wire" circuit.

Speech signals from subscribers arrive at the radio terminal at widely different average levels, owing to the differences in subscribers' average talking volumes and in the transmission losses of inland connections, and superimposed upon these differences are the normal modulations of a subscriber's talking volume. A radio telephone transmitter which could provide, over a long-distance circuit, an acceptable signal-to-noise ratio with the lowest speech levels yet not be overloaded by the highest speech levels would be of exorbitant cost and size and for most of the time would be operating inefficiently. If, however, the average modulation of the transmitter is maintained at a high and substantially constant level a major economy in

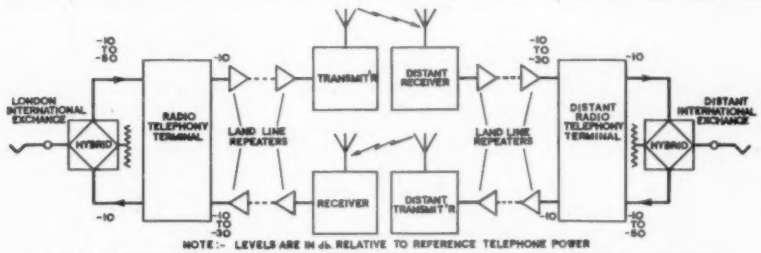


FIG. 2.—BLOCK SCHEMATIC DIAGRAM OF LONG-DISTANCE RADIO TELEPHONE CIRCUIT.

† Mr. Sowton is Senior Executive Engineer and Mr. Balchin Executive Engineer, Radio Planning and Provision Branch, Engineer-in-Chief's Office.

transmitter size and power can be obtained. This condition is achieved by inserting, in the transmit path at the R.T.T., an automatic variable gain amplifier which maintains a constant output speech volume over a wide range of input volumes. This unit is known as a " transmit constant volume amplifier."

Radio signals transmitted via the ionosphere are subject to both general and selective fading—with selective fading the different frequency components of the signal fade in and out independently of one another. In double-sideband radio telephone systems, the average level of the emitted radio signal, i.e. of the carrier plus sidebands, is constant and, but for fading, the average level of the received signal would also be constant. Fading can, therefore, be adequately compensated in the receiver by short time-constant automatic gain-control circuits responsive to the average level of the received signal. In single-sideband radiotelephone systems, however, no such constancy of signal level exists since the level of the emitted radio signal varies with the modulation depth, so a pilot carrier is also emitted at a constant low level for automatic gain control at the receiver. The time-constant of the A.G.C. circuit used in this case must be relatively long (of the order of ten seconds), so that while it responds to general fading, which usually occurs at a relatively slow rate, it ignores the rapid variations in level to which the carrier may be subject due to selective fading. Although by this means the output of the receiver is maintained at a substantially constant average level, it may still be subject to short-term variations of up to 20 db. These variations have to be corrected by means of a device known as a " receive constant volume amplifier " which is generally located at the R.T.T.

Radio frequency noise of continuously varying level may be associated with the received signal, and in multichannel radio telephone systems interchannel crosstalk may also be present. The effect of noise and crosstalk on the intelligibility of speech may be reduced by limited range volume expansion in the receive path, so suitable expanders are included in radio terminal equipment.

At the radio terminals at each end of the circuit, gain may have to be inserted in the transmit and receive paths as the levels shown in Fig. **2** indicate. The net gain in a go or return channel between the hybrid transformers is dependent on the subscribers' speech level and may approach 40 db. in the extreme case. The loss across each hybrid transformer, however, (which is mainly dependent on the two-wire balance) is often as low as 20 db., sometimes even lower, and thus in the loop circuit formed by the go and return channels, there may be a net gain of more than 40 db. Singing, which would otherwise inevitably occur, has to be prevented by the use at the radio terminals of voice-operated singing suppressors, which block the transmit path while the receive path is open for the passage of speech signals and vice-versa.

The primary requirements so far outlined are met for each radio-telephone circuit by the provision at the R.T.T. of a unit of apparatus known as a " terminal bay." Most circuits, however, require additional apparatus such as privacy equipment and channelling equipment (for multichannel systems) and this is also installed at the radio terminal to facilitate the engineering operation and supervision of the complete radio-telephone circuit. Finally, monitoring and testing equipment and an extensive network of telephone " speaker " circuits to the radio transmitting and receiving stations and to the International exchange are also required.

Circuit Arrangements

Basic Circuit.

With the general nature of a long-distance radio telephone circuit and the necessity for the various types of apparatus in mind, the basic circuit arrangements of the radio terminal equipment will be considered in more detail. Referring to Fig. **3**, speech incoming to the London International exchange from the inland network passes through the hybrid transformer H1 and over a landline to the Brent R.T.T. where it is amplified by the transmit constant volume amplifier (T.C.V.A.) to a constant average level at the point " A." (A manually-operated gain control and transmit amplifier are also provided, for use in place of the T.C.V.A. for lining-up the radio circuit on tone and for other purposes.) The speech then passes via static relays to the radio transmitting station. In the receive path a receive constant volume amplifier (R.C.V.A.) removes the residual rapid fluctuations in speech level due to selective fading and provides a constant speech volume at its output. The speech signals continue via the static relays to a limited range volume expander, which is used to improve intelligibility by reducing the effective noise level, and arrive at a predetermined constant level at the point " B." A receive amplifier with preset gain adjustment permits final control of speech level to the exchange but its more important function is to prevent speech signals from the exchange reaching the point " B."

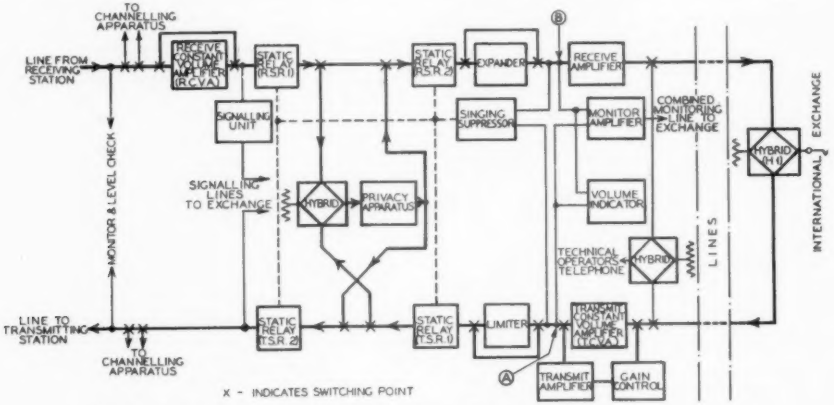


Fig. 3.—Block Schematic Diagram of Radio Telephone Terminal Equipment.

The static relays TSR1 and 2 and RSR1 and 2 which form part of the singing suppressor are metal rectifier networks which can be made to have either low or extremely high insertion losses by changing the direction of a D.C. control current flowing through them. The control current is generated in the singing suppressor and its direction, which determines whether the transmit path is open and the receive path blocked or vice-versa, is dependent on the relative signal levels at the points "A" and "B". The need for two static relays in each path is due to the use of privacy equipment on a "two-wire" basis. Privacy equipment is expensive and considerable economy can be effected by using the same apparatus for both directions of transmission, as indicated in Fig. **3**, but this introduces a second potential singing path and requires the provision of additional static relays.

Transmit Path.

Radio telephone transmitters are adjusted to give a standard modulation depth when 1 mW of tone is applied at the measuring point "A" (Fig. **3**). The working modulation depth for speech signals is then dependent on the speech volume, which is maintained at a substantially constant pre-determined level at the point "A" by the transmit constant volume amplifier, which for a range of input levels from −50 db. to −10 db., R.T.P.* delivers a constant output volume of −10 db. ± 3 db., R.T.P. Fig. **4**,

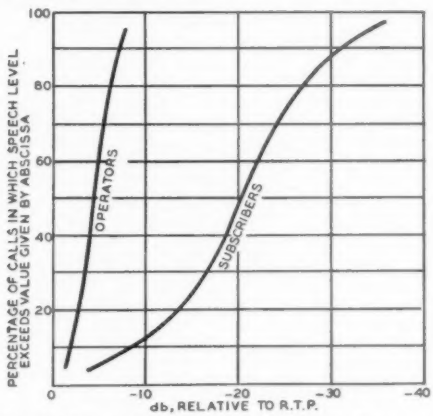


FIG. 4.—SPEECH LEVELS AT INTERNATIONAL EXCHANGE.

which has been drawn from measurements of speech volumes in about 800 telephone calls during two weeks in 1949, is illustrative of the range of speech volume from subscribers and from operators at the International exchange, and it will be seen that the T.C.V.A. adequately caters for all volumes likely to be received from subscribers. The automatic operation of the T.C.V.A. is fully effective only while a D.C. signal is received from the International exchange, which is the condition while a subscriber is actually connected; the absence of this signal sets the gain of the T.C.V.A. to a low value suitable for the high speech levels from both technical and traffic operators. When the speech input level increases, the gain of the T.C.V.A. begins to decrease within about two milliseconds and the correct output level is attained in some 20 milliseconds. When the speech level decreases, the gain remains almost unchanged for about one second and then rises at a rate such that the correct output level is attained in about five seconds.

* The abbreviation "db., R.T.P." is used throughout to indicate speech volume in decibels relative to Reference Telephonic Power.

These characteristics maintain substantially constant speech volume during passages of speech, reduce overloading of subsequent apparatus, yet preserve most of the natural modulations of speech occurring at syllabic frequency. In the absence of a speech signal input, the T.C.V.A. gain remains at the setting determined by the last passage of transmitted speech, to allow for the natural pauses in conversation. A circuit is incorporated for discrimination against operation by line noise, which is usually of a steady character as distinct from the syllabic nature of speech. A connection (not shown in Fig. **3**) from the singing suppressor is provided to prevent the gain of the T.C.V.A. from being affected by speech signals from the receive path traversing the hybrid transformer H1.

To ensure the highest working efficiency for Post Office radio telephone transmitters the modulation depth used at present is such that slight overloading occurs at the peaks of most syllables. To minimise interchannel crosstalk in multichannel systems, however, it is desirable that overloading should not occur at or after the point at which channels are combined, and it is proposed to insert peak limiters in all terminal equipment, as indicated in Fig. **3**. Field trials of these limiters, now proceeding, indicate that their use will permit an increase in average modulation depth at the expense of speech quality, but, nevertheless with a resultant improvement in intelligibility of received signal when the signal-to-noise ratio is poor.

Receive Path.

The R.C.V.A.s used at Brent R.T.T. provide a constant speech volume of −10 db. ± 2 db., R.T.P. for a range of input volumes of −10 to −30 db., R.T.P. An auxiliary control circuit causes the gain of the R.C.V.A. to be set to 0 db. for input volumes below −32 db., R.T.P., so that relatively low-level noise or crosstalk is not amplified in the absence of a speech signal and thus in the intervals between passages of speech the noise level is normally reduced. This threshhold level of −32 db. may be increased to −24 db., R.T.P. to cater for conditions of high noise level. The response of this device, although fast enough to correct the speech volume variation due to selective fading is not sufficiently fast to follow syllabic variations. Although the most probable value of signal-to-noise ratio is between 32 and 40 db., it falls below the minimum allowable value of between 20 and 25 db. for 2 per cent. to 10 per cent. of the scheduled times of the services. The percentage of time "lost" on this account may be reduced by the use of limited range expanders which are provided in each terminal equipment. For signal input levels down to a preset datum level, the output level of the expander is the same as the input level, but as the input level drops n db. below this datum level the output level falls $2n$ db. The expander is said to have a 2 : 1 expansion characteristic in terms of levels measured in db. below the datum level; for example, if the datum level is −15 db., then for an input level of −25 db. the output level would be −35 db. The time required for the appropriate output level to be established after the input level changes is about 20 mS, which is sufficiently short for the expander to be able to follow changes occurring at syllabic rate. The speech signal amplitudes are generally above the datum level and the speech wave form is reproduced faithfully except for slight distortion at the beginnings and ends of syllables. In the intervals between syllables or words the expander output falls to that appropriate for the level of noise or crosstalk and (assuming that this level is below the datum level) the expander causes the noise or crosstalk to be reduced in level relative to the signal. The reduction in the disturbing effect of noise or crosstalk improves the intelligibility of the speech despite the slight distortion of the

speech signals. The distortion could be virtually eliminated by the use of compressors in the outgoing channels at radio terminals, but the distortion is so small when expansion is applied to the lower speech amplitudes only that the provision of compressors is not considered to be worth while.

Suppression of Singing.

The net gain which may exist around the four-wire loop formed by the outgoing and incoming channels and the two terminal equipments is unlikely to exceed 48 db., even with quite low loss across the hybrid transformers, and as the static relays of the singing suppressor have insertion losses which change from 2 db. to 110 db. according to the direction of speech transmission, effective control of the direction of transmission is attained. In the absence of speech signals the static relays in the receive path are in the condition of low loss and those in the transmit path are of high loss. When a speech signal from the near-end subscriber reaches the point " A " (Fig. **3**) in the transmit path, a portion of it is amplified in the control amplifier in the singing suppressor, and then rectified to operate a " trigger " type of thermionic relay. The operation of the thermionic relay reverses the direction of the D.C. control current through the static relays, thus reducing the attenuation in the transmit path to a low value and inserting a high attenuation in the receive path. This operation is completed within some two milliseconds and results in slight but generally imperceptible " clipping " of the initial sounds of a passage of speech. On the cessation of the speech signal the original " no signal " condition of the singing suppressor is not restored until some 180 mS. have elapsed; this "hangover" time is sufficiently long to cover the normal intervals between words and avoids clipping at the beginning of each word or syllable. When speech is passing in the receive direction, a signal is taken from the constant level point "B" (Fig. **3**) in the receive path, and is amplified and rectified to provide a D.C. control signal, which reduces the gain of the control amplifier of the singing suppressor. This, and the stabilisation of the T.C.V.A. gain during receive speech, prevent unwanted operation of the thermionic relay by speech from the receive path traversing the hybrid transformer H1 and reaching the point " A," and also prevents the near-end subscriber " breaking in." This control from the receive path has a " hangover " time of some 60 mS. to prevent false operation by echo signals from the two-wire line. Radio noise of high level in the receive path will also reduce the gain of the control amplifier in the singing suppressor in the same way as do speech signals (since for a speech volume of —10 db., R.T.P. the power averaged over a short interval may be only of the same order as that of the noise) and the gain may be so reduced that speech signals of normal level in the transmit path are unable to operate the thermionic relay. To overcome this a manual adjustment is provided to enable the sensitivity of the control from the receive path (" receive sensitivity ") to be reduced at times when the radio noise level is high.

The adjustments which are provided enable the singing suppressor to handle nearly all the possible adverse combinations of inland transmission loss, poor return loss and high radio noise, but in a small number of cases (less than 2 per cent. in a sample count) a call has to await less unfavourable conditions.

Signalling and Control.

Non-automatic signalling between the international exchanges at the ends of long-distance radio telephone circuits is provided by means of 500/20 c/s or 1,000/20 c/s signals (according to the arrangements at the distant terminals) transmitted over the radio channels. The radio terminal bays at Brent incorporate apparatus for converting D.C. signals from the exchange to 500/20 or 1,000/20 c/s signals, and for receiving 500/20 c/s signals. P.O. Units, Signalling, No. 9 are used for the incoming signals. The signal conversion takes place at the transmit path output and the receive path input of the radio terminal bay, the singing suppressor and privacy equipment being by-passed by the D.C. signals.

Four pairs of lines are provided between the R.T.T. and the International exchange, for each radio circuit. Two pairs are used for the radio channels, one pair for a monitoring signal fed from the R.T.T. to the exchange, and one pair for an order wire between the technical operator and the traffic operator. The various D.C. signals and associated circuits have been described in an article[1] on the International exchange (formerly known as the Overseas exchange).

Details of the various telephone and control facilities

[1] *P.O.E.E.J.*, Vol. 41, p. 76.

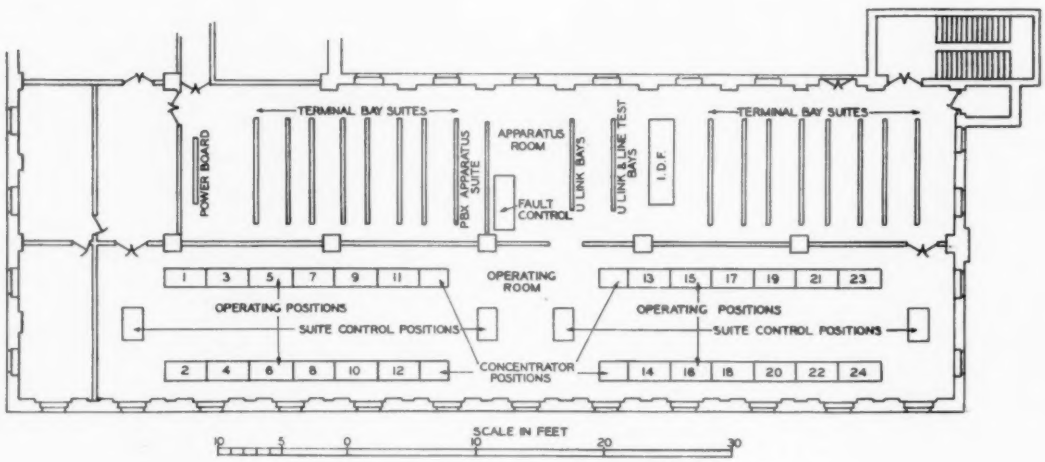


FIG. 5.—LAYOUT OF EQUIPMENT ON 1ST FLOOR AT BRENT R.T.T.

available to the technical operators are given in the next section.

Layout and Equipment

To facilitate the supervision of the radio circuits by a relatively small staff, the controls necessary for the operation of a number of circuits should be grouped in close physical proximity. At the Brent R.T.T. this has been achieved by segregating the control and supervisory equipment from the rest of the terminal apparatus. The privacy and channelling equipments have also been segregated from the main terminal apparatus, to permit full flexibility in the interconnection of these equipments, and to facilitate the specialised maintenance required for the privacy equipment.

The R.T.T. equipment has been installed on the first and ground floors of the building and on the first floor there are (*a*) an apparatus room containing the terminal bays and miscellaneous equipment ; (*b*) an operating room containing the positions from which remote control of the terminal bays is effected and where the other control and supervisory facilities required by the technical operators are provided. The layout of this equipment is illustrated in Fig. **5**.

The ground floor accommodates (*a*) an apparatus room containing privacy equipment and channelling equipment (the initial installation of channelling equipment provides for one 4-channel system, three 3-channel systems and 14 2-channel systems) ; (*b*) operating positions and apparatus for dealing with the transmission of broadcast programmes; and (*c*) a small studio provided for special purposes.

Fig. **6**.—A Terminal Bay.

Terminal Bays and Associated Apparatus.

The terminal bays, as illustrated in Fig. **6**, are assembled in suites, and associated with each pair of suites are test and miscellaneous apparatus bays which provide comprehensive facilities for transmission testing and routine performance checking, power switching and distribution, tone and pulse distribution and interconnection of terminal bays and operating positions. Included in the performance checking apparatus is a ½-millisecond chronometer of the electronic pulse-counting type (recently developed by the Post Office) for timing the operate and release periods of the voice-operated devices in the terminal equipment.

The initial installation is 48 terminal bays but the apparatus room will accommodate approximately 100 bays and associated equipment. Extensive patching facilities are provided for testing purposes and to enable faulty equipment to be replaced by spares. A special injection-cum-extraction ventilating system has been installed to ensure adequate cooling of the apparatus and the room in general.

Channelling and privacy equipment is connected into the circuits of the terminal apparatus through U-link fields and a distribution frame to facilitate short-term or long-term reallocations of the types of channelling or privacy apparatus.

Operating Positions.

Four suites of six operating positions are installed, and Fig. **7** shows two of the suites (with concentrator positions

Fig. **7**.—View of Two Suites of Operating Positions and Associated Control Positions.

at the near ends) and associated suite control positions. Fig. **8** is a close-up of an individual operating position. In

Fig. **8**.—An Operating Position.

the centre of each position is a " Position Control Panel " on which general telephone and monitoring facilities are available and flanking this are four " Circuit Control Panels " from each of which control of one radio circuit via a terminal bay can be effected. Thus, by keys and rotary switches on the circuit control panels adjustments can be made to the transmit and receive sensitivities and receive hangover time of the singing suppressor, the threshhold level of operation of the R.C.V.A. and the gain of the transmit amplifier. Test speech from a continuously replayed tape recording, or test tone at standard level (either continuous or pulsed) can be applied to the transmit path of the terminal equipment or directly to line, and a morse key provides for keyed tone transmissions. The technical operator can ring over the radio circuit and

extend the ringing facility to the traffic operator at the International exchange.

The position control panel provides monitoring and speaking facilities for the four radio circuits connected to the position. Volume indicators are provided for the measurement of speech volumes and tone and noise levels on any of the circuits. The monitoring, volume indicator, and speaking facilities are indicated in Fig. 3. Each position has two extensions from the Brent P.B.X., and private wire speaker circuits to the radio transmitting and receiving stations are multipled over all operating, programme control and concentrator positions. Other direct telephone circuits connect with the International exchange, the Brent apparatus rooms, and the operating room Supervisors.

The facilities which can be extended to the concentrator position at the end of each suite are monitoring, International exchange speaker circuit and P.B.X. extensions. A lamp display shows the circuits which have been transferred to the concentrator position, at which the operator is able to check occasionally the condition of any radio circuit controlled by him, and to communicate with the exchange and the radio stations. Overall supervision is exercised by engineering officers at the suite control positions.

Programme Control Positions.

For broadcast work three programme control rooms and a studio are provided. Programme material is carried over point-to-point radio telephone circuits for retransmission by broadcasting organisations or for the use of private concerns. This type of traffic, which demands the highest quality transmission, is handled in four-wire circuits without hybrid transformers, singing suppressors, privacy or any of the special equipment used for telephone traffic. The frequency bandwidth is generally at least 5·5 kc/s, and high-quality microphones are used. Duplicate channels may be provided as reserves, and sometimes it is necessary to switch and interconnect a number of radio channels and landline channels converging on the Brent R.T.T.

One of the programme control positions for controlling and switching networks of landlines and radio circuits used in international relays of broadcast programmes and public addresses is shown in Fig. 9. The two centre panels contain a clock, volume indicators, monitoring loudspeaker, switches for inter-connecting channels, and manual gain

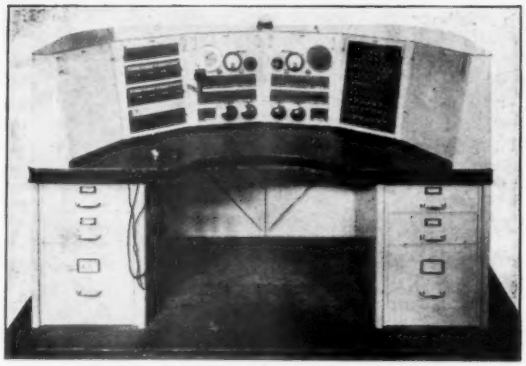


FIG. 9.—A PROGRAMME CONTROL POSITION.

controls. Automatic gain controls of the T.C.V.A. type, expanders, amplifiers, and associated apparatus are mounted on separate equipment bays. The two outer panels in the programme position contain telephone keys giving access to the landline network, and a U-link field for testing and interconnection purposes.

Conclusion.

The improvement in the signal-to-noise ratio of long distance radio-telephone circuits which has been made by the introduction of single-sideband systems and otherwise, has facilitated the automatic control of the circuits at the R.T.T. thus avoiding the need for continuous monitoring and frequent manual adjustment of individual circuits. The introduction of multi-channel working has resulted in a further reduction in the technical supervision necessary for each circuit, since many of the control operations (e.g. arranging for changes of radio carrier frequency to suit varying propagation conditions) are now common to several circuits. These factors have had a major influence on the design of the new R.T.T. at Brent, and whereas at the Faraday R.T.T. one technical operator was required for each circuit, at Brent R.T.T. an operator normally controls up to four circuits.

Future development may tend towards the remote control from the R.T.T. of transmitters and receivers for long distance point-to-point radio-telephone systems.

Book Review

"Microwave Measurements." H. M. Barlow, B.Sc.(Eng.), Ph.D., M.I.E.E., and A. L. Cullen, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E. Constable & Co., Ltd. 399 pp. 214 ill. 30s.

Recent years have seen many applications of microwaves to communications and it is likely that the future will see an increased use of such waves for the radio relaying of television and telephony. Progress in this field, as in many others, depends on the ability to make measurements accurately and readily. This book is welcomed for the very real contribution it makes to the theory and practice of microwave measurements.

The first three chapters are introductory and contain a well-written and clear statement of the fundamental characteristics of guided waves and the transformation of wave impedance using the circle diagram, followed by a description of the characteristics of cavity resonators. The next six chapters are concerned with the measurement of fundamental quantities such as wavelength and frequency, power, attenuation, the properties of materials, including permittivity and loss factor, impedance and standing-wave ratio. This section of the book is especially useful and is of wide application, since the emphasis is primarily on the fundamental theory and principles rather than on the details of the equipment.

Two chapters are given on the measurements of the characteristics of transmitters and receivers; these are written mainly from the radar standpoint and are of less value to the communications engineer. The final chapter discusses briefly the measurement of the gain and radiation pattern of aerials. The book includes a number of theoretical appendices, including an excellent treatment of the theory of wave impedance transformation.

This book is confidently recommended to all engineers concerned with the design, operation and maintenance of radio equipment operating in the centimetric waveband.

W. J. B.

I.P.O.E.E. Library No. 1960.

An Application of Equaliser Curves to the Design of Two-Terminal Networks

P. W. SEYMOUR, A.M.I.E.E.†

U.D.C. 621.392.4

A method is described which permits a two-terminal network, possessing a desired impedance (modulus)/frequency characteristic, to be derived from design data readily available for a four-terminal constant impedance equaliser, having an insertion-loss/frequency characteristic similar in shape to the required impedance (modulus)/frequency characteristic.

Introduction.

In the design of line communication amplifiers, it is often convenient to carry out part or total line equalisation by means of a suitable electrical network in the amplifier feedback circuit. Under certain conditions which are related to the principles of negative feedback amplifier design, this electrical network may assume the form of a two-terminal network.

The determination of a sufficiently accurate impedance (modulus)/frequency characteristic for this two-terminal network, either empirically or by calculation can involve considerable labour.

It was found, however, as described below, that if an insertion-loss/frequency characteristic of a particular form of four-terminal constant impedance equaliser could be selected which suitably fitted the shape of the required impedance (modulus)/frequency characteristic, then the element values of the two-terminal network could be rapidly calculated from data which are available for the four-terminal network.

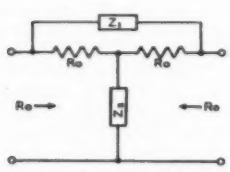


FIG. 1.—GENERAL FORM OF CONSTANT IMPEDANCE EQUALISER (R_o BEING THE EQUALISER RESISTANCE).

The convenience of the method is due to the fact that families of curves representing the insertion-loss/frequency response of four-terminal constant impedance equalisers are readily available.[1]

Insertion-Loss/Frequency Characteristic of a Four-Terminal Equaliser.

The general form of a four-terminal constant impedance equaliser is shown in Fig. **1**, in which the impedance arms Z_1 and Z_2 are inverse networks. Fig. **2** shows a particular form of Fig. **1**, which

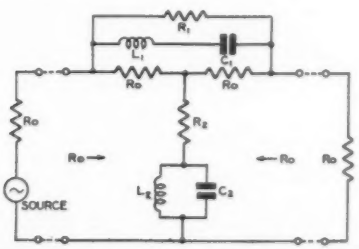


FIG. 2.—PARTICULAR FORM OF CONSTANT IMPEDANCE EQUALISER OPERATING BETWEEN SOURCE AND LOAD EACH OF RESISTANCE R_o.

is widely used for equalisation purposes and gives an insertion-loss/frequency characteristic of the form shown in Fig. **3**.

Considering Fig. **2** and evaluating the mesh equations, it can be shown that the modulus of the ratio obtained by dividing the current I_t (which flows in the load resistor R_o when the source is connected to it directly) by the current I_o (which flows in the same load resistor R_o when the network is inserted between the source and this load) is given by :—

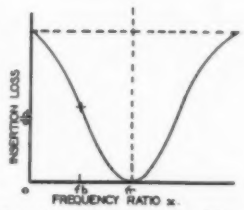


FIG. 3.—INSERTION-LOSS/FREQUENCY CHARACTERISTIC FOR EQUALISER SHOWN IN FIG. 2.

$$\left|\frac{I_t}{I_o}\right|^2 = 1 + \frac{K^2-1}{1+K\left\{\frac{m}{x-1/x}\right\}^2} \quad \ldots\ldots\ldots\ldots (1)$$

and the insertion loss, A, in decibels, of the network is :—

$$A = 20\log_{10}\left|\frac{I_t}{I_o}\right| = 10\log_{10}\left\{1 + \frac{K^2-1}{1+K\left\{\frac{m}{x-1/x}\right\}^2}\right\} \quad \ldots (2)$$

where, $m = b - \frac{1}{b}$

$b = \omega_b/\omega_r$, where $b>1$

$x = \omega/\omega_r$

$\omega_r = 2\pi f_r$ = resonant angular frequency of the impedance arms Z_1 and Z_2

$\omega_b = 2\pi f_b$ = angular frequency of one half pad loss

$\omega = 2\pi f$ = any angular frequency

and K is defined by the equation, Pad Loss (maximum loss in db.) $= 20\log_{10} K$

A re-arrangement of expression (2) gives :—

$$A = 10\log_{10}\left\{\frac{K^2(x^2-1)^2 + Km^2x^2}{(x^2-1)^2 + Km^2x^2}\right\} \quad \ldots\ldots\ldots\ldots (3)$$

Impedance Characteristic of a Two-Terminal Network.

Consider the network shown in Fig. **4**. The impedance of this network at any angular frequency ω can be shown to be :—

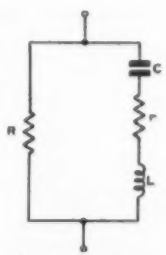


FIG. 4.—FORM OF TWO-TERMINAL NETWORK.

$$Z = \frac{R\left(r + j\omega L + \frac{1}{j\omega C}\right)}{\left(R + r + j\omega L + \frac{1}{j\omega C}\right)} \quad \ldots (4)$$

If now the constants P and Q are introduced, then, defining them as $P = R/r$, and $Q = \omega_r L/r = 1/\omega_r Cr$, expression (4) may be written :—

$$Z = R\left\{\frac{Q(1-x^2) + jx}{Q(1-x^2) + jx(1+P)}\right\} \quad \ldots\ldots\ldots (5)$$

or

$$\left(\frac{|Z|}{R}\right)^2 = \frac{Q^2(1-x^2)^2 + x^2}{Q^2(1-x^2)^2 + x^2(1+P)^2} \quad \ldots\ldots (6)$$

where ω_r and x have their previous meanings.

† P.M.G.'s Department, Australia (formerly Executive Engineer, P.O. Research Station).

[1] P.O. Research Report No. 11867.

The impedance (modulus)/frequency characteristic of the two-terminal network may now be represented for this purpose by the expression :—

$$N = 20 \log_{10} \frac{|Z|}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

which is in the form of expression (2) and conveniently permits N to be plotted on the same scale as A, the insertion loss of the four-terminal network; it being noted that the above expression and that for the insertion loss are functions of a common independent variable, x.

At the resonant angular frequency, ω_r, the above expression (7) will thus assume a minimum value of :—

$$20 \log_{10} \frac{1}{1 + P}$$

Comparison of the Four-Terminal and Two-Terminal Results.

The insertion-loss/frequency characteristic of the four-terminal network given by expression (3) could now be compared with the characteristic obtained by plotting $20 \log_{10} |Z|/R$ against frequency. However, inspection of expression (3) shows that at the resonant angular frequency ω_r, the insertion loss becomes zero ; so, to allow the four-terminal and two-terminal network characteristics to have the same minimum value at this resonant angular frequency the expression for $|Z|/R$ can be multiplied by a factor $(1 + P)$, and expression (3) then compared with the characteristic obtained by plotting $20 \log_{10} (1 + P) |Z|/R$ against frequency.

If now some simple relations are imposed between the basic parameters of the networks, it is possible to make the characteristic obtained by plotting $20 \log_{10} (1 + P) |Z|/R$ against frequency have exactly the same shape as the characteristic obtained by plotting expression (3) against the same frequency axis.

The necessary relations are :—

$$K^2 = (1 + P)^2 \text{ and } Km^2 = \frac{(1 + P)^2}{Q^2}$$

Since there are an infinite number of two-terminal networks which will give the required characteristic, it is desirable to evaluate the element values in terms of R, the highest value of impedance which the two-terminal network assumes. Hence, in the case of a given two-terminal network design, R and ω_r are determined by the nature of the particular problem for which the network is intended. For example, in the case of an amplifier design, as mentioned in the introduction, R may bear a simple relation to the gain of the amplifier at the theoretical limits of zero and infinite frequency ; and where the maximum gain occurs at ω_r. Hence R and ω_r may be determined for this problem.

Assuming that the two-terminal network will be operating in a constant-current feedback circuit, it then remains for a suitable equaliser characteristic to be chosen by trial to match the particular characteristic required for the feedback circuit. Element values can then be calculated for the two-terminal network using the following relations which involve the values of b and K :—

$$L = \frac{R}{\omega_r} \cdot \frac{\sqrt{K}}{K-1} \cdot \frac{b}{b^2-1} \quad \ldots\ldots\ldots\ldots (8)$$

$$C = \frac{1}{\omega_r R} \cdot \frac{K-1}{\sqrt{K}} \cdot \frac{b^2-1}{b} \quad \ldots\ldots\ldots\ldots (9)$$

$$r = \frac{R}{K-1} \quad \ldots\ldots\ldots\ldots (10)$$

Conclusion.

The treatment has been confined to the well-known section in Fig. 2, and the success of the method is due to the availability of prepared families of insertion-loss/frequency characteristics for this section.

It is probable that the method could be extended to certain more complicated equaliser sections and their transfer into more complicated two-terminal networks. The success of the method would, however, again depend upon the availability of prepared families of insertion-loss/frequency characteristics relating to the chosen sections.

For those interested in this subject much useful information is contained in " Motion Picture Sound Engineering" (Chapters XVI and XVII, by Harry Kimball), published by D. Van Nostrand Company Inc., New York.

Acknowledgment.

The author is indebted to Mr. W. T. Duerdoth, who indicated that some simple relations of the form obtained should exist, and gave guidance in this work.

Book Review

"Technical Instruction for Marine Radio Officers." H. M. Dowsett, M.I.E.E., F.Inst.P., and L. E. Q. Walker, A.R.C.S. Iliffe & Sons, Ltd., London. 699 pp. 700 ill. 60s.

This volume is the ninth edition of a handbook of technical instruction for wireless telegraphists originally published in 1913, this latest edition appearing under a slightly different title from the earlier editions. The fact that it has, since its first appearance, passed through so many editions is a clear indication of the popularity and usefulness of the book and that the authors are fully alive to the need for keeping pace with the development of radio technique and practices.

As the title implies, the book is written primarily for the marine radio officer with the object of providing him with simple instruction in the principles and practice of radio equipment associated with the maritime radio service. To-day, a radio officer is likely to be in control of and operate equipment employing radio frequencies lying in the range between 16 kc/s and 9,000 Mc/s, and to gather together in a single volume the more important features of such equipment is no mean task and one which the authors have accomplished with some success. A balance has been struck between the theoretical and practical aspects of the subject with the emphasis, quite properly, placed on the practical side whilst, at the same time, giving the reader sufficient theoretical background to understand the principles underlying the practical applications.

With such a wide field, it must have been difficult to decide what material to omit and what to include, and, in this respect, the authors' choice can be criticised on some points. They might well have excluded such items as the quadrant electrometer, the wave aerial, and short-wave arrays, which can only be of academic interest to the average marine radio officer, and given the space to more detailed discussion of the practical difficulties of radio communication. Many ships are now fitted with equipment working in the frequency range 4-25 Mc/s for long-range communication and, to obtain the advantages of such equipment, it is most important that the propagational properties of these high frequencies should be well understood. The authors have not given this aspect the attention it deserves and, even in the propagation curves that are included for the guidance of radio officers, a figure of 10 kW of radiated power is used in their derivation which is very much higher than likely to be met with on the average ship. Another less important criticism is the continued use of wavelengths when frequency would be a more appropriate term.

Apart from these minor criticisms, the book, which contains such a large amount of practical information on such a complex subject, can be confidently recommended to radio officers as an invaluable source of information and guidance. E. P.

The Manchester-Edinburgh Television Radio Relay System

U.D.C. 621.397.743

THE main Scottish television broadcast transmitting station now under construction at Kirk O'Shotts, a point about midway between Edinburgh and Glasgow, is being connected to the television relay network by means of a radio system linking Kirk O'Shotts and Manchester. Invitations to tender for this radio system were issued by the Post Office early in January last year, the contract being placed with Standard Telephones & Cables in June, 1950.

The route, shown in Fig. 1, was influenced to some extent

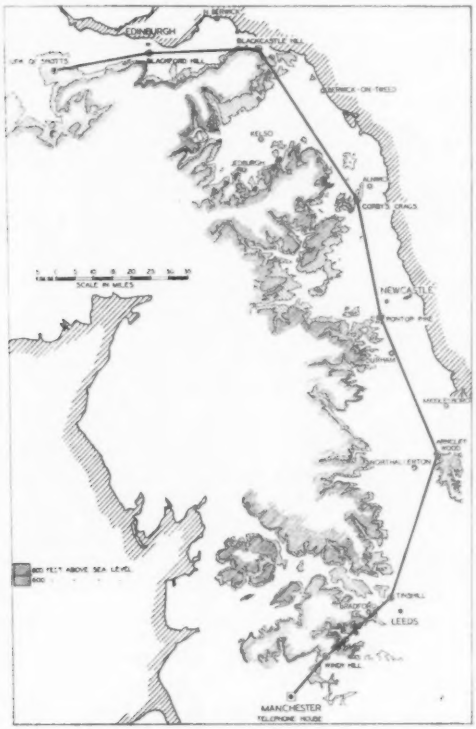


FIG. 1.—ROUTE OF MANCHESTER-EDINBURGH BROAD BAND RADIO RELAY LINK.

by the requirement that it should pass reasonably close to Newcastle to enable a short spur to be provided at some future date for the proposed B.B.C. television station for that area, and also by the desirability of passing near Leeds and Edinburgh so that programmes could be injected at the intermediate relay stations near these towns—a new requirement for television relay systems. In fact, this facility will be provided at all relay stations. The longest link will be some 46 miles, and the total mileage nearly 250.

Before detailing the radio equipment, it may be of interest to indicate the main respects in which it will differ from the London-Birmingham radio system which has already been described[1]:—

(i) It will operate at the much higher frequency of 4,000 Mc/s.

(ii) Although it will provide for two-way simultaneous operation, only two carrier frequencies will be used throughout the system compared with the four required for the full two-way installation between London and Birmingham. Both frequencies will be used alternately throughout each channel, but any one link in the chain will use different frequencies in the two directions.

(iii) The equipment will all be housed in a single building at each station, and only the aerial system will be located at the top of the masts.

(iv) A travelling wave amplifier is used as the output stage of each repeater and terminal transmitter, this being the first commercial application of this technique.

(v) The receivers and transmitters will be connected to their respective aerial systems by means of waveguides, the first commercial use of these by the Post Office.

Since it is too early to give more than a brief description of the equipment, the main points of difference will be emphasised and details having a resemblance to the existing radio system omitted.

A typical mast may be 50 ft. or so in height and carry four paraboloid aerials, each some 10 ft. in diameter, and connected to the radio equipment at the base of the mast by waveguide transmission lines, the lines being filled with dry nitrogen under a pressure of about $\frac{1}{2}$ lb. per sq. in., to prevent internal corrosion. The paraboloids will have a gain of about 40 db. relative to a half-wave dipole, and an angular beam width of about $2\frac{1}{2}°$. At Blackcastle Hill, a 220-ft. mast is required to provide the necessary clearance over the difficult terrain on the two links radiating from it.

A schematic of a typical transmitter for use at a terminal station is shown in Fig. 2. The incoming video signals

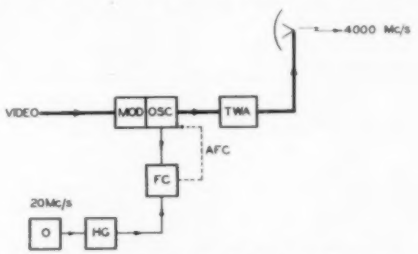


FIG. 2.—BLOCK SCHEMATIC DIAGRAM OF TERMINAL TRANSMITTER.

from the B.B.C. switching centre are applied to the reflector electrode of a klystron (MOD/OSC) oscillating at the radiated frequency. This produces a frequency modulated signal, the mean frequency of which is stabilised by an automatic frequency control loop (AFC). This loop derives its controlling action from a frequency comparison (FC) of the radio frequency oscillator (OSC) with that of a stable reference signal derived from a harmonic generator (HG) which is driven by a 20 Mc/s crystal-controlled oscillator (O). The output of the klystron oscillator is amplified by the travelling wave amplifier (TWA). The novel features of this valve are its aperiodicity, that is, its ability to amplify signals over a very wide range of frequencies, its relatively high gain, and its relative simplicity. The gain of the wave amplifier is some 17 db., and its output power 1 W.

[1] *P.O.E.E.J.*, Vol. 43, p. 23.

The output of the amplifier is connected by a waveguide to the focus of the paraboloid reflector.

The probable arrangement of equipment at a relay station is shown in Fig. 3. It will be seen that the incoming

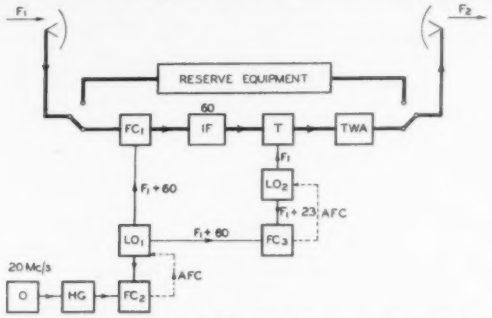


FIG. 3.—BLOCK SCHEMATIC DIAGRAM OF TYPICAL REPEATER.

signals are applied to a crystal frequency changer (FC_1), converted to an intermediate frequency of 60 Mc/s, and amplified. The frequency of the coaxial line oscillator (LO_1) is stabilised by an automatic frequency control loop (AFC) using a reference frequency derived from a harmonic generator (HG), driven from a crystal oscillator (O) having a frequency of 20 Mc/s. The frequency of the outgoing signals has to differ by some 37 Mc/s from that of the incoming signals. This is achieved by applying the I.F. signals to a hybrid mixer unit (T), which includes a balanced crystal frequency changer, and mixing them with the output of a local oscillator (LO_2) whose frequency has been stabilised to the appropriate value by the second A.F.C. loop. This second A.F.C. loop is controlled by comparing the frequency output of the oscillator (LO_2) with that of the oscillator (LO_1) which, as already mentioned, is continuously stabilised by comparison with the 20-Mc/s crystal oscillator. By this means frequency stability throughout the system is assured. Finally, the output of the crystal mixer (T) goes via a waveguide filter which selects the wanted sideband and passes it to a travelling wave amplifier and thence to the outgoing aerial waveguide.

As in the case of the London-Birmingham link, standby equipment is being provided, together with comprehensive remote control and supervisory facilities, which uses a 4-wire line interconnecting all stations. Additional accommodation is being provided at Newcastle to cater for the future spur extension and at Kirk O'Shotts for a future extension to Aberdeen.

A. H. M-

Book Reviews

PHILIPS TECHNICAL LIBRARY (*Series on Electronic Valves*). N. V. Philips' Gloielampenfabrieken, Eindhoven. Distributed in the U.K. by Cleaver-Hume Press, Ltd.

Book I: "Fundamentals of Radio-Valve Technique." 535 pp. 384 ill. 35s.

This is the first of a series of seven books on electronic valves now being published by the well-known Dutch firm of N. V. Philips. Since it appears that the volume under review has already been published in Dutch, English, French, German and Swedish, while Italian, Spanish, and Finnish editions are in preparation, one is led to expect a series of more than ordinary merit. If the standard of this first volume is maintained few will be disappointed.

The fundamental physical principles underlying the operation of electronic devices are explained in a clear and comprehensive manner, and the book can be recommended to anyone wishing to obtain a good knowledge of the basic theory of radio valves. Manufacturing processes are described in some detail, and operational difficulties such as hum, microphony, negative grid current, and insulator charging effects are discussed more fully than is usual in books on valves. Mathematical analysis has been used where it is essential, but is of an elementary character, and the unnecessary use of advanced or elaborate mathematics has been wisely avoided. A commendable feature is the use of the rationalised m.k.s. system of units, and the inclusion in an appendix of a clear account of Giorgi's system for readers not already familiar with it. The appendix also contains a useful collection of summarised data in the form of definitions, formulæ, tables and graphs. R. W. W.

I.P.O.E.E. Library No. 1962.

Books II and III: "Data and Circuits of Receiver and Amplifier Valves." Book II: 405 pp. 532 ill. 21s.; Book III: 220 pp. 267 ill. 12s. 6d.

These books are in effect a detailed catalogue of the valves developed in the Philips Research Laboratories at Eindhoven, Holland, during the years 1933-1940 (Book II) and 1940-1941 (Book III); additional books are promised to cover valves developed in subsequent years. The valves surveyed comprise receiving, amplifying and rectifying valves, current regulators and stabilisers; also other electronic devices such as cathode-ray tubes, photo-electric cells, electronic indicators and various secondary emission devices. The technical data included are exceptionally complete; for example, curves are given showing the cross-modulation and hum-modulation characteristics of R.F. amplifiers and the distortion characteristics of A.F. amplifiers, as well as the more usual characteristics relating to electrode voltages and currents. Circuit diagrams for a range of radio receivers, including A.C., A.C./D.C. and battery types, and gramophone amplifiers are given to illustrate typical applications of the various types of valve. A range of test equipments comprising A.F. and R.F. oscillators, oscilloscopes, measuring bridges and other items developed in the Philips Research Laboratories are also described.

It is perhaps a matter for regret that only Philips valves are described in these volumes; a similarly comprehensive and detailed survey of other makers' valves would have been of great value to the equipment designer.

Book IV: "Application of the Electronic Valve in Radio Receivers and Amplifiers." 467 pp. 256 ill.

This book is the first of three volumes on the applications of valves in radio receivers and amplifiers. This volume deals with the following aspects of receiver and amplifier design: R.F. and I.F. amplification; frequency changing; oscillator tracking problems in super-heterodyne receivers; distortion due to causes such as non-linearity of valve characteristics, modulation-hum, cross-modulation, production of whistles; and finally the various methods of detection. Other matters such as A.F. power amplifiers, H.T. and L.T. supplies are to be treated in later volumes.

The subject is discussed both descriptively and analytically, the treatment being exceptionally thorough. A feature which is especially commended is the large amount of measured data, derived mainly from tests made in the Philips Research Laboratories, which has been included and which will be of considerable assistance to radio receiver designers. Each chapter concludes with a survey of the literature on the subject matter of that chapter; these surveys include many references to work in Dutch, French and German technical periodicals and serve perhaps as a reminder that these countries have made notable contributions in this field.

W. J. B.

Commonwealth Telecommunications

Under the auspices of the Commonwealth Telecommunications Board, a meeting of telecommunications engineers and traffic experts of Commonwealth countries, presided over by Sir Stanley Angwin, was held in London between 16th October and 3rd November 1950. The objects of the meeting were to provide a general review of recent technical developments in radio and cables, including the research work in telecommunications, in hand, or projected, in each country, and the application of these developments to the Commonwealth system.

Representatives attended from the United Kingdom, Canada, Australia, New Zealand, South Africa, India, Pakistan, Ceylon, Southern Rhodesia, the Gold Coast, Nigeria, Trinidad, British Guiana, Singapore and Malaya. Officers from the Engineering Department and the Overseas Telecommunications Department took part in all the discussions and visits, and provided many of the papers.

A wide measure of agreement was reached on a number of scientific, engineering and traffic matters in regard to the Commonwealth network of wireless and cable communications. Recommendations have been submitted in a confidential report to the Commonwealth Telecommunications Board, which will in due course submit its findings to the respective Governments.

A. H. M.

Back row, left–right: H. Everett (Assistant Secretary, Commonwealth Telecommunications Board (C.T.B.), Secretary of the Meeting); E. G. L. Howitt (Assistant Traffic Manager, Cable & Wireless, Ltd.); G. H. Webster, C.M.G., O.B.E. (Colonies Member, C.T.B.); D. C. Balaam (Overseas Telecommunications Department, G.P.O.); J. H. Tudhope (Canadian Member, C.T.B.); Lieut.-Colonel H. Myers, O.B.E. (South African Member, C.T.B.); D. F. Bowie (Canadian Overseas Telecommunications Corporation); D. G. Peck (Assistant Controller of Telecommunications, Singapore and Malaya); J. C. Dallow (Controller of Telecommunications, Singapore and Malaya); J. Briggs (Acting Assistant Engineer-in-Chief (Wireless), Nigeria); A. H. Mumford, O.B.E. (Staff Engineer, G.P.O.); A. M. Humby (Royal Naval Scientific Service and British Joint Communications Board).

Middle row, left–right: P. A. Courtnay (Director of Posts and Telegraphs, Nigeria); N. S. Wickremasinghe (Superintending Telecommunications Engineer, Ceylon); Colonel A. H. Read, O.B.E., T.D., D.L. (United Kingdom Member, C.T.B.); N. C. Chapling (Traffic Manager, Cable and Wireless Ltd.); J. G. Young, C.B.E. (New Zealand Member and Vice-Chairman, C.T.B.); F. A. Binden (Cable and Wireless Ltd.); Dr. R. L. Smith-Rose (Director of Radio Research, Department of Scientific and Industrial Research); H. J. Hutchinson (General Traffic Supervisor, Overseas Telecommunications Commission (Australia)); S. R. Kantebet (General Manager, Overseas Communications Service, India); C. F. Brimblecombe (Southern Rhodesian Member, C.T.B.); J. L. Creighton (Telecommunications Liaison Officer, Colonial Office); V. H. Winson (Consulting Engineer, Crown Agents for the Colonies); H. Faulkner, C.M.G. (Deputy Engineer-in-Chief, G.P.O.); J. A. Smale (Engineer-in-Chief, Cable & Wireless Ltd.); K. W. Hargrove (Office-in-Charge, Government Wireless Service, Trinidad); A. F. E. Evans, O.B.E. (Engineer Officer, C.T.B.); D. J. Robinson (Senior Wireless Engineer, Posts and Telegraphs Department, Gold Coast).

Front row, left–right: A. E. Gagan (Acting Engineer-in-Chief, Posts and Telegraphs Department, British Guiana); G. Apperley (Australian alternate Member, C.T.B.); L. S. Payne (Canadian Overseas Telecommunications Corporation); E. H. R. Green (Chief Engineer, New Zealand Post Office); Rt. Hon. Lord Reith, G.C.V.O., G.B.E., C.B., T.D. (Chairman of C.T.B.); Colonel Sir A. Stanley Angwin, K.B.E., D.S.O., M.C., T.D. (Chairman of the Meeting and Chairman of Cable & Wireless Ltd.); R. V. McKay (Australian Member, C.T.B.); M. N. Mirza (Chief Engineer, Posts and Telegraphs Department, Pakistan); A. S. McDonald (Chief Engineer, Overseas Telecommunications Commission (Australia)); Colonel W. W. Shaw-Zambra, C.B.E., T.D. (Secretary-General, C.T.B.)

Notes and Comments

New Year Honours

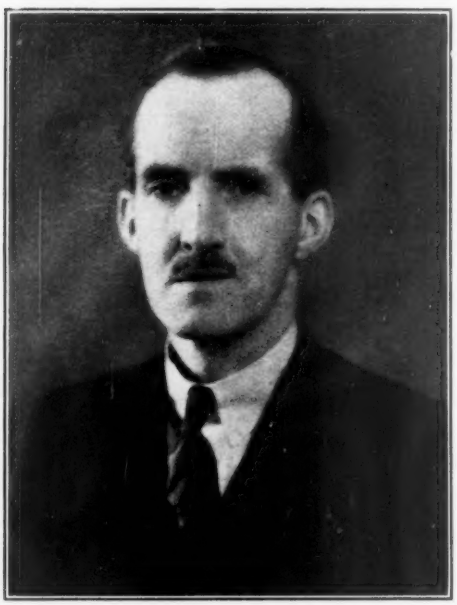
The Board of Editors offers congratulations to the following members of the Engineering Department honoured by H.M. the King, in the New Year Honours List :—

Engineering Department	Turner, A.	Technician, Class I	British Empire Medal
Guildford Telephone Area	Pendry, S. D.	Executive Engineer	Member of the Order of the British Empire
H.M.T.S. "Monarch"	Tilly, T.	Radio Operator	British Empire Medal
Leicester Telephone Area	Healey, S.	Lately Technician, Class I	British Empire Medal
London Telecomms. Region	Gregory, E. G. S.	Assistant Engineer	Member of the Order of the British Empire

Obituary—Mr. J. Morgan, O.B.E., A.R.C.Sc., M.I.E.E.

John Morgan, O.B.E., A.R.C.Sc., M.I.E.E., Chief Regional Engineer, Welsh and Border Counties Region, died on 12th January, 1951, following an operation on the previous day.

Born at Sheerness on 22nd December, 1890, he entered the Dockyard as an engine-fitter apprentice in 1905, taking first place in the examination; he attended the Dockyard school for four years and, in 1909, won a Whitworth Exhibition and a Royal Scholarship, which enabled him to further his technical education at the Royal College of Science, South Kensington. He was awarded a 1st Class Diploma of the College in mathematics and mechanics in 1912, and continued as a post-graduate student at the City and Guilds Institute until his entry to the Engineering Department as Assistant Engineer in 1913, taking second place in the open competitive examination.



He was first appointed to the Local Lines Section of the Engineer-in-Chief's Office, and was transferred in 1914 to the Exeter Section. He served with commissioned rank in the R.E. Signals in France, and on demobilisation returned to Exeter, where he remained until 1924. After a further period of five years in the Local Lines Section he was promoted Sectional Engineer at Exeter, and in 1934 to Assistant Superintending Engineer, Scotland West. He came south again to Bristol in 1936 and succeeded Mr. P. T. Wood as Superintending Engineer in 1938. As Chief Regional Engineer, he was transferred to Cardiff in 1944, where he carried out the dual duties of C.R.E. and D.R.D. His services to the Post Office were recognised by his inclusion in the New Year Honours List, 1949.

By his sound judgment, fairness and humanity he earned the esteem and respect of all grades: of a quiet and retiring disposition, he shunned the limelight, but was firm and convincing in the presentation of his views. From his youth he had always taken a keen and active interest in a number of indoor and outdoor sports and, indeed, excelled in some. He was a member of the Penarth Golf Club, and looked forward to his Saturday afternoons on the course with some of his friends and colleagues in the Region.

He was a gentle and affectionate husband and father—he leaves a widow and one daughter—and found much happiness and contentment in family life. A staunch nonconformist, he was at the time of his death a Deacon of Christchurch, Penarth, a fitting tribute to his Christian way of life. He was sympathetic and kind to those in adversity and his generosity in any case of need which came to his notice was a secret he withheld even from his most intimate friends.

As a good companion and a loyal friend John Morgan will be sadly missed.

W. F. B.

Journal Changes

Since 1934, there have been very few changes in the appearance of the Journal and such as have been introduced were of a minor character. With the current issue, however, readers will notice, possibly with some regret, that the generous page margins to which they are accustomed, have now been considerably reduced due to the adoption of a revised format.

This change, designed to economise in paper without reducing the contents of the Journal, will assist materially in offsetting rising production costs and will, it is hoped, avoid the necessity for increasing the price of the Journal.

At the same time, opportunity has been taken to introduce a new Journal cover styled on more modern lines, but retaining the clarity of layout which has proved popular in the past.

Corrections

In the article on National Trunk Dialling, published in the previous issue of the Journal, there is a typographical error on page 171. The demand traffic completed over two trunk links is 93 per cent., and not 3 per cent., as stated.

In Fig. 1 (*b*) on the same page, the wrong symbol is shown for the C relay, which is a 2-winding relay, but without slug.

Retirement of Capt. J. Legg, I.S.O., B.Sc.(Eng.), A.M.Inst.C.E., A.M.I.E.E.

Capt. J. Legg, Assistant Engineer-in-Chief, retiring on 31st March after 39½ years' service in the Post Office, entered the Engineering Department by examination as an Assistant Engineer (as the title then was) in 1911. He had been a student at King's College, London, where he obtained his Engineering Degree and later served for two years as a Pupil Apprentice at the Royal Ordnance Factory, Woolwich. His early experience in the Post Office was in

the Test and Inspection Branch where his service was broken by the first World War in which he served from 1914-1919, reaching the rank of Captain.

Later he was Assistant Staff Engineer and then Staff Engineer in charge of the Telephone Development and Maintenance Branch during a period which saw spectacular development in the local telephone service and the change-over to "on demand" working on the trunk service throughout the country. This improvement in the service given by trunks, together with the 1s. night calls which were introduced during this period, were the means of causing extremely rapid growth which the Department found some difficulty in meeting. He was promoted Assistant Engineer-in-Chief in 1941, and until 1944 was in charge of the Engineering Department's activities out-stationed at Harrogate.

He has been closely concerned with training and welfare and was largely concerned with the setting up of the Engineering Department Residential School at Stone which has proved of such great value.

He acted as Chairman of the British Telephone Technical Development Committee for about 10 years during which period many important developments in the standardisation of switching plant took place. For some years he has been Chairman of the Sub-Committee of the 8th Study Group of the International Telephone Advisory Committee, charged with the development and trial of the methods of signalling and dialling on international circuits, which will no doubt prove invaluable to our future international communications.

He was responsible for the recent reorganisation of the Draughtsmen grades and has been Chairman of the Assistant Engineers' and Draughtsmen's Promotion Boards.

He was a very keen tennis player and twice played in the singles championships, and with his brother in the doubles at Wimbledon. A few years ago he took up golf, where his capacity for going "straight down the middle" served him in good stead; he was a very popular captain of the Engineering Department Golf Society in 1949.

His sound judgment on telephone matters and his pleasant personality will be sorely missed by his colleagues. We wish him every happiness in his retirement and a favourable "rub of the green" in his future activities.

H. F.

Mr. A. H. Mumford, O.B.E., B.Sc.(Eng.), M.I.E.E.

Mr. A. H. Mumford, who has been appointed Assistant Engineer-in-Chief on the retirement of Capt. J. Legg, entered the Department as a Probationary Assistant Engineer in 1924, after completing his studies at East London College, and ever since has been concerned primarily with radio. After a short period in the City, he joined the band of enthusiasts at the Dollis Hill Laboratory, was promoted to Executive Engineer in 1933, to Assistant Staff Engineer in 1935, and three years later returned to the City as Staff Engineer of the Radio Branch.

At Dollis Hill Mr. Mumford was particularly concerned with short and ultra-short wave radio systems and with

multi-channel telephony and television transmission over coaxial cables. He had a considerable bent for experimental work and, as his responsibilities increased, showed the attributes needed to build up, and to lead, a large team. He took charge of the Radio Branch at a time when radio was playing an increasingly important role in both civil and military communications and between 1939 and 1945 he carried heavy responsibilities. His efforts during this

period were recognised by the well-merited award of the O.B.E. in 1945. During his period as Staff Engineer the Radio Branch was split into three separate Branches dealing respectively with Planning and Provision (WP), Development and Experiment (WE) and with Station Operation and Maintenance (WM), and he took over WP Branch. His one break with the work of the Radio Branches was during 1948, when he attended the Imperial Defence College.

In the last five years Mr. Mumford has been particularly occupied with the international aspects of radio and has attended many international conferences. Those who have been concerned with post-war radio conferences will realise the burden that this work must have entailed.

Following the pattern set by his predecessors, Mr. Mumford has been active in the work of the Radio Section of the I.E.E. He has been a member of the Section Committee for some 15 years and was Chairman of the Section in the 1945-1946 Session. He made the Students' Lecture Tour in 1947-1949 and gave the L.C.C. Children's Lecture in 1951. He has contributed several papers to the I.P.O.E.E., was Chairman of the London Centre, 1947-1948, and has been a frequent contributor to this Journal, of which he has been a member of the Board of Editors for many years.

It is characteristic of Mr. Mumford that he has found time to lead his team as a Staff Engineer, to make major contributions to post-war radio conference work and to the Radio Section of the I.E.E. He has unbounded energy, an analytical mind (which he can readily focus on diverse problems, sometimes with devastating effect) and the quality of leadership, all of which are cemented with a ready wit. These qualities will serve him well in whichever sphere he is directed and will enable him to grapple with the problems awaiting him in his new post. All his immediate colleagues, in fact, all who have been privileged to come into contact with him, will say "well done, and good luck for the future."

C. F. B.

Institution of Post Office Electrical Engineers

Festival of Britain, 1951

A number of subscribers to the Journal who live abroad and Corresponding Members of the Institution may be visiting England for the Festival of Britain, 1951. On behalf of the Institution, we should like to extend them a cordial welcome and hope that they will get in touch with the Secretary, Col. J. Reading, Equipment Branch, Engineer-in-Chief's Office.

While in Great Britain, they may wish to visit various Post Office installations, such as exchanges and repeater stations, etc., and we should be very pleased to make any necessary arrangements.

Recent Additions to the Library

1957 *Electric Cables.* F. W. Main (Brit. 1949.)
Deals with the construction, technical characteristics and manufacture of electric cables for lighting, power, telegraphy and telephony.

1958 *Large-Scale Organisation.* (Ed.) G. E. Milward (Brit. 1950).
An authoritative account of how eleven great industries and services are organised.

1959 *Wood Adhesives.* E. H. Pinto (Brit. 1948).
Covers the use of a large range of adhesives from the technical, commercial and economic points of view.

1960 *Micro-Wave Measurements.* H. M. Barlow and A. L. Cullen (Brit. 1950).
Presents, primarily, those techniques of wide application, particular attention being given to principles of operation rather than details of apparatus.

1961 *Radio Aerials.* E. B. Moullin (Brit. 1949).
Intended mainly for those concerned with the electromagnetic aspects of the design of short-wave aerials.

1962 *Fundamentals of Radio—Valve Techniques.* J. Deketh (Dutch 1949).
Aims at giving technicians and research workers a lucid account of the properties, functions, assembly and applications of radio valves.

1963 *Short Wave Radio and the Ionosphere.* T. W. Bennington (Brit. 1950).
Presents in simple form, avoiding the use of mathematics, all the available information on the role of the ionosphere in long-distance short-wave communication.

1964 *Protective Coatings for Metals.* J. W. Gailer and E. J. Vaughan (Brit. 1950).
Describes the most important of the various films or coatings applied for the protection of the more commonly used metals; the theory of their action; the methods of application; and the scientific choice of coatings for particular environments.

1965 *University Text-book of Physics.* Vol. II. (Sound) Poynting and Thomson (Brit. 1949).
Designed to serve those taking Honours Courses in branches of Science other than Physics, who have chosen Physics as a subsidiary subject for their degree.

1966 *Concrete Construction.* C. E. Reynolds (Brit. 1950).
Describes the temporary and permanent work in the construction of most plain and reinforced concrete structures.

1967 *Electronics.* P. Parker (Brit. 1950).
Written from the point of view of a physicist interested in the applications of a branch of his subject, it is intended to provide a background for the circuit specialist, and a starting point for the tube specialist. Roughly of the standard expected in the electronics Paper for the London first degree in engineering.

1968 *Advanced Mathematics for Technical Students.* Pt. II. Lowry & Hayden (Brit. 1950).
Covers the work normally done by students taking mathematics as a subject in Part II of an engineering degree.

1969 *Semi-Conductors.* D. A. Wright (Brit. 1950).
Gives an elementary account of their properties, being especially concerned with the theory of electron flow in them, and across the boundary between them and either a metal or a vacuum.

1970 *Engineering Science.* Vol. III. H. B. Brown and A. J. Bryant (Brit. 1950).
Mainly concerned with experimental work, testing and full-scale trials of prime movers, to the standard required for the Ordinary National Certificate Course in Mechanical Engineering and the Engineering Science of the Ordinary National Certificate in Electrical Engineering.

1971 *A.C. Motor Windings.* H. Hopwood (Brit. 1950).
Written with the intention of explaining some of the rules peculiar to A.C. armature windings.

Regional Notes

Northern Ireland Region

STORM DAMAGE

The arrival of the New Year was heralded by a short but severe freak snow storm in the Belfast Telephone Area. During the early hours of 1st January, a heavy fall of snow caused extensive damage over an area of some 2,000 square miles. All overhead plant east of a line from Limavady in the north, to Newcastle, Co. Down, in the south, was affected. The weather conditions favoured the " build up " of snow on the line wires, and as a result, approximately 160,000 wires were broken and the remainder were stretched beyond tolerance limits. Practically every wire in the affected area will have to be renewed. In addition, some 40 poles were broken and several hundreds deflected, whilst many stays were pulled or broken. In all, about 11,000 subscribers' lines (including 320 emergency lines) and 300 trunk and junction circuits were put out of service. Belfast Central and its satellite exchanges had 6,400 lines faulty out of a total of 29,269 working lines, while in some of the U.A.X. areas every subscriber's line was out of order. A total of 40 exchanges were isolated.

At the end of the first day it was apparent that the normal staff in the Area would be unable to cope with the repair work, and other Regions were asked for assistance. Response was excellent, and altogether 14 gangs were kindly lent, complete with lorries and tools, from the Liverpool, Birmingham, Leicester, Newcastle-on-Tyne, Bristol, Exeter, Gloucester, Taunton and Brighton Areas. This assistance was much appreciated and greatly helped in the preliminary restoration of service.

To effect speedy restoration of service on a temporary basis, use was made of covered wire, Army D8 cable, interruption cable and recovered wire. A special Central Storm Repair Control was set up to deal with the temporary repairs. The main function of this Control was the deployment of gangs to meet the constantly changing requirements of the situation. In addition to the main Control, seven detached Control Centres were introduced, each being under the direction of an Assistant Engineer who implemented the instructions given by the Central Control. This proved to be a most satisfactory arrangement. The Control Officers from the detached Centres supplied information daily to the Central Control. First priority was given to the restoration of the more urgent emergency lines (hospitals, fire stations, etc.), 50 per cent. of the trunk and junction circuits, the clearance of road obstacles, and broken poles dangerous to property.

With the exception of rural kiosks all faults on emergency circuits, and 50 per cent. of the junction circuits, had been cleared at the end of the first week. The methodical restoration of other services in each exchange area was then carried out in geographical D.P. order.

Although one in seven of the staff was sick due to the severe influenza epidemic prevalent at the time, the unstinted efforts of the combined staffs enabled the temporary restoration of all damage to be completed by 31st January. From surveys made of typical exchange areas by the Area Development Group, it was estimated that 66 gangs will be required to complete the repair work before the arrival of next winter.

A novel feature of the damage caused by the storm was the displacement of a section of a steel pole, the top section of the pole turning out of alignment at the first joint due to uneven breaking of the wires.

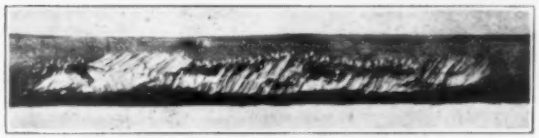
E. H. W.
T. S. W.

North Eastern Region

CABLE DAMAGE BY SQUIRREL

While locating a cable breakdown in a 15-pair cable, it was observed that the U.G. cable from the terminal block on a D.P. which was served by aerial cable, had been badly gnawed for a distance of 6 ft. from the terminal block ; in one place the conductors were exposed. In addition, the aerial cable had also been damaged in the same way from the point of exit from the terminal block, to approximately 4 ft. from the pole.

The route concerned is adjacent to a densely wooded area in which grey squirrels abound, and they have often been seen climbing the poles and running along the aerial cable. Although the " culprit " was not caught " at work," it can clearly be seen from the accompanying photograph that the cable had been damaged by sharp teeth, and there appears to be little doubt as to how the damage was caused.



DAMAGE CAUSED BY SQUIRREL TO 15-PAIR L.C. CABLE.

A. J. C. H.

Home Counties Region

BARMING A.T.E. FIRE

On the 18th December, 1950, at 2.0 a.m., an emergency lineman was called out to attend to a prompt alarm at Barming A.T.E., a satellite exchange in the Maidstone multi-office area. On arrival, he found the building full of smoke and the exchange lighting out of order. Entering the building, he crawled through the smoke and removed the fuses from the main battery and cut off the electricity and gas supplies. The smoke was so dense that he could not locate the source, and so he then summoned assistance from the nearest telephone connected to another exchange. The fire was then located and extinguished with teletetra extincteurs.

The outbreak occurred on a 100-line, line switch and final unit (one of four) and the upper half was completely burnt out, including jumpers, cabling, and connection strips. Cabling to the next unit was also destroyed together with the ceiling immediately over the unit and the lead-covered electric light cabling.

The damaged equipment was disconnected and the remaining two units put back into service by 5.0 a.m. Arrangements were then made for all incoming calls to the affected units to be routed to the manual board at Maidstone, and full service was given to five kiosks and 22 emergency subscribers by shifting them to the unaffected equipment and allocating temporary numbers.

Information was received that a unit could be obtained from Headington exchange in the Oxford Area, and whilst this was being collected the damaged unit was recovered and the ceiling repaired by the Ministry of Works' contractor. Cabling was also renewed to the fourth unit. At 3.0 p.m. on 19th December, the unit arrived from Headington and all subscribers were restored to service by 10.0 p.m. on 21st December. Considerable trouble was caused by deposits of soot and beads of lead which had splashed over the equipment in a molten state. This necessitated cleaning all banks, wipers, and electrical contacts on the switches, and somewhat delayed the restoration of full service.

It is considered that the initial handling of the situation by the emergency lineman and the subsequent efforts of all staff reflects great credit on all concerned.

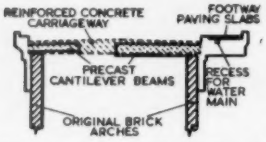
C. W. C.

RECONSTRUCTION OF HONEYWOOD BRIDGE

Honeywood Bridge, near Folkestone, is part of the A.20 trunk road where it crosses the railway between Sandling Junction and Westenhanger station. For many years it has remained a bottleneck to the traffic along this road and recently the Ministry of Transport planned to widen it, to provide two lanes for vehicles and a footway.

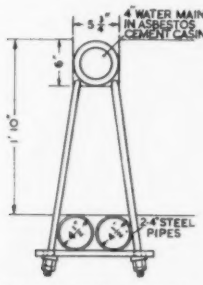
The design for the reconstruction of the bridge comprised the building of precast, reinforced concrete cantilever beams on to the existing brick arches to support a reinforced concrete road. It will be seen from the illustration that the cantilever beams are incorporated in the concrete road, and that the footway extends beyond the brick arch.

As the Post Office was considering an underground main cable route between Ashford and Folkestone, the Ministry of Transport was asked if provision could be made for two 4-in. steel pipes to be laid across the bridge, but it became clear from discussion that, owing to the novel design, normal methods were impracticable. Provision had already been made in the design, for a 4-in. water main to be laid in a 6-in. square recess in each of the cantilever beams under the footway paving slabs. As any enlargement of these slots would have seriously weakened the cantilever, the same method could not be adopted for the P.O. pipes. It was decided, however, that subject to a maximum loading of 32 lb. per ft. run for pipes and cables, two 4-in. steel pipes could be slung underneath the beams, directly under the water main, and secured by stirrups hung from the slots.



SECTION OF RECONSTUCTED BRIDGE.

This work has now been carried out and the two 4-in. steel pipes are securely fixed below the overhanging footway. The stirrups (shaped like an inverted letter U), two to each beam, were made locally from ¾-in. round mild steel, heavily galvanised, and were positioned prior to the laying of the water main. The pipes were then hoisted into position and clamped against the underside of the beams by plates of 15 in. × 2½ in. × ⅜ in. galvanised mild steel. As a precaution against vibration, lock nuts were fitted, and to protect against corrosion all the threads were liberally coated with tallow tar and pitch composition.



METHOD OF SUSPENDING CABLE PIPES.

As a matter of interest, before the reconstruction work commenced, a Bailey bridge was slung across the railway cutting, alongside the old bridge, by the 61st Engineering Squadron of the 36th Army Engineering Regiment, to provide for the light road traffic, vehicles of 20 tons and over being diverted along the Hythe Road. H. J. P.

STORM DAMAGE—GUILDFORD AREA

The severe snow storm on the 2nd January caused widespread damage over most of the Guildford area to the extent of 8,120 subscribers' lines becoming out of order. This followed the snow storm of only eight months previously when 14,200 lines were affected, as reported in the July 1950 issue of the Journal. Again the Guildford area was by far the most severely hit in the Home Counties Region.

The recent damage was appreciably extended on two occasions some days later by gales which increased the number of lines affected to over 10,000. The main damage was caused by the weight of snow on the wires, without accompanying wind, and resulted in a mass of odd-wire breakages both in subscribers' drops and also along routes, this time without pole breakages whereas in the previous storm the greater build-up of snow caused consequent pole breakages to an overall total of some 410.

On the earlier occasion the heaviest routes, irrespective of size of conductor, were the most damaged. In the January storm, however, there was no damage to conductors above 40 lb. Where most of the wires along rural routes were down, about 10 miles of interruption cable has been used.

The centralised control system to deal with priorities, stores, etc., for the restoration of the heavier routes, as mentioned in the previous note, was not found of much value on this occasion. Instead, decentralisation to the maximum extent was employed, resulting in individual field Inspectors having wide powers over the gangs under their immediate control. Each Inspector was responsible for gangs working in a well-defined territory, the control being used more as a message centre and to receive information, e.g. on the movement of gangs from one exchange area to another.

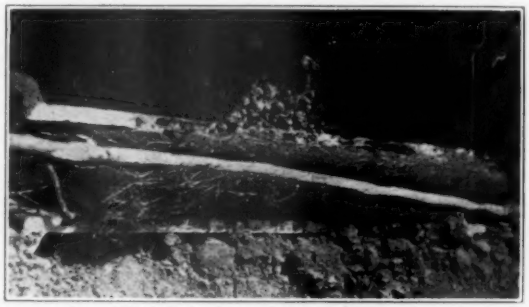
Permanent repairs were effected initially in the great majority of cases, the exceptions being where interruption cable was used. The exchange areas affected were completely surveyed by the planning staff, but investigations are now proceeding to determine whether, in fact, this work was necessary or profitable, at least for the general type of damage caused by this storm.

Thanks to the sustained efforts of some 65 gangs and 2-man parties (including 18 borrowed from surrounding Areas), together with the maintenance and auxiliary staffs and supervising officers, service was restored to all subscribers by the evening of the 22nd January. H. M. W.

COM-"BAT WILLOW"

Considerable difficulty has been experienced on major works by the mass root formation of the Bat Willow tree (*Salix caetulea*). This tree is found in large numbers in Essex and is usually planted to support and retain river banks. Its wood is used for the manufacture of cricket bats

The illustration shows fibrous roots, which have entered a


BAT WILLOW ROOTS FILLING DUCT.

duct line at a coupling point, completely filling the adjoining ducts and split coupling and forcing the cable to the top of the duct. L. G. H.

North Western Region

TECHNICAL EDUCATION

The Lancaster Telephone Area is now completing the fourth year of a systematic and sustained drive in the technical education of its staff. In the three completed years, engineering personnel have gained 352 City and Guild Certificates, the average area-staff-strength over the last three years being well under 500 men. The Area is large (over 3,000 square miles) and there are six main centres of staff concentration. These several groupings of staff in small units, with their differing employment and technical standards, have presented obstacles to the organisation of classes and the willing support of the staff has been the main contributory factor in overcoming the difficulties encountered.

In the winter of 1946-47 there existed in the area one class only; this was in the subject Elementary Telecommunications Practice. The general technical knowledge of the Area staff was then regarded as capable of improvement, and a decision was made to initiate a recruitment drive for technical classes. It was appreciated that the projected scheme could only succeed with the large-scale co-operation of the staff, and that considerable and prolonged publicity would be necessary to obtain this co-operation.

Following a period of intensive publicity and within about four weeks of the opening of the 1947-48 session, meetings were held at all centres, and the staff was addressed, advised and recruited with the result that the session opened with 12 classes. During subsequent sessions, and between sessions, no opportunity was lost to emphasise that technical classes had come to stay.

The continued success of the recruiting methods is indicated by the fact that 18 classes are running in the current session, divided thus: Lancaster 5, Carlisle 4, Kendal 3, Barrow 2, Whitehaven 2 and Penrith 2.

In each year the ratio of 1st Class to 2nd Class certificates has been higher than the national average, and a very pleasing feature of the 1950 examination successes is that the 2nd, 3rd and 4th year subject certificates taken together exceed the number of 1st year certificates.

The classes were taken (with very few exceptions) by Executive Engineers, Assistant Engineers and Technical Officers, and the scheme owes a large part of its success to these tutors' efforts. An average of 117 City and Guild Certificates each year over a period of three years from a staff of less than 500 (including external staff) is considered an achievement. J. D.

ASHTON-IN-MAKERFIELD EXTENSION NO. 2

This exchange—described in a previous article*—was a non-standard satellite exchange parented on Wigan. When an extension became necessary, it was agreed by Headquarters in 1947 that a "turn round" to a 2,000-type satellite exchange was desirable to avoid the manufacture of non-standard equipment. Owing to the limited rack space available and the height of the racks (8 ft. 6 in.), it was not possible to introduce uniselectors, and linefinder working was therefore continued. The "turn-round" in situ was effected by reducing gangway clearances and allowing for two stages of installation, accomplished as follows.

The existing traffic recorder rack was recovered and the old line and cut-off relay rack was shifted out of line. This allowed for the erection of the new line and cut-off relay, primary finder, satellite 1st selector, discriminator and final selector racks to cover the transfer of the existing 400 subscribers' multiple. Fortunately, sufficient space existed for the extension of the main distribution frame, and additional verticals were provided to cable the new exchange as a separate entity, thus providing a simple method of changing over to the new equipment. Owing to the restricted accommodation, it was not possible to replace all the existing apparatus, and therefore the old relay set, alarm equipment, meter and group selector racks were retained for further use and by various rearrangements the new equipment was installed on these racks. Sufficient space existed on the old meter rack for 400 new meters and these were installed and, after the initial cut-over, the old meters were recovered and the final 200 meters were fitted in their place.

The retention of rack 7A presented an interesting problem, the final scheme requiring the replacement of the existing 100-outlet group selectors by 200-outlet group selectors, so that these outlets could be associated with the 200-outlet satellite 1st selectors. It was found that by re-distributing the outlets on shelf A over the remaining shelves B, C and D, it would be possible to recover the shelf of 100-outlet banks and install in its place a shelf of 200-outlet banks. By reducing the number of incoming manual board circuits, it was also possible to reduce the total incoming circuits to 10.

After extensive testing, the new portion of the exchange was satisfactorily cut into service on 6th September, 1950. Within a week of this, the contractor had recovered the remaining shelves B, C and D of the 100-outlet selectors and fitted the two shelves of 200-outlet selectors, thus restoring the availability of the incoming routes to normal proportions. The old line and cut-off, group finder and final selector racks were then recovered and the remaining new primary finder, satellite 1st selector and final selector racks were installed in their place, thus completing the "turn-round." In addition to this, new miscellaneous equipment such as meter routine test, service interception, trunk offering and traffic recorder, was also installed. Last, but not least, a new power plant, batteries and ringing machines were provided.

The exchange premises consist of two buildings with approximately 30 ft. by 14 ft. and 17 ft. by 14 ft. floor space available for apparatus and power plant, respectively. The buildings are connected by a covered passage way and the cables connecting the equipment have been arranged with "bights" to avoid disconnections by possible subsidence of the site due to coalmining. From the foregoing it will be appreciated that there was extreme congestion of space during most of the installation period, and much credit is due to the staff of the Automatic Telephone & Electric Co. for their installation work and to the Department's maintenance staff who had to keep the old exchange working under very trying circumstances. The final stage of the work was satisfactorily completed on 30th November, 1950. G. J. S.

* *P.O.E.E.J.*, Vol. 27, p. 290.

Welsh and Border Counties Region

BUILDING MANHOLES IN RUNNING SAND

The Chester Area was recently concerned with a contract for the construction of 51 manholes of the R1A and R2D concrete types, and at first no great difficulties were anticipated in the work. Commencing at the Chester end, the first three manholes were built in normal ground, but further excavations indicated that serious trouble was likely to arise from the type of subsoil encountered.

It was found that the route passed directly over what appeared to have been an old river bed and the manholes would, therefore, be in running sand with a water level about 3 ft. below the surface. De-watering was considered to be the best solution and as, during the war years, a Lee Howl pump had been modified for this work it was decided, for economic reasons, that the Post Office would accept responsibility for operating this plant in making the excavations.

At the commencement of de-watering operations, four well points were sufficient and the Lee Howl equipment was found to be very satisfactory. It became evident later, however, that a second pump would be necessary and one was therefore hired. The continuous use to which the two pumps were subjected caused many small and recurrent mechanical difficulties, but reasonable progress was maintained with this simple equipment.

Early in September, 1950, an effort was made to construct an R2D manhole, but after three days pumping it was realised that the two pumps were inadequate. As an alternative to the expense of hiring a single pump of adequate capacity, it was decided to hire a third small pump and adapt it for use with a set of well points lent by the Regional Training School. By means of the three small-capacity pumps, the contract was completed and it is estimated that the improvised methods resulted in a saving of about £2,074 in hiring charges. Rapid-hardening cement was used as far as possible, but, as supplies of this cement were difficult to obtain, much ordinary cement had to be used and the pumps run for longer periods in consequence.

Each manhole has since been carefully inspected and apart from minor leaks in two manholes all others are satisfactory.

The experience obtained in carrying out this contract shows that by the use of de-watering plant satisfactory building of manholes in running sand is possible and it may be well worth while having equipment of this type available in a central pool of mechanical aids. G. B.

South Western Region

INTRODUCTION OF MULTI-METERING AT TAUNTON

The first major change-over of an existing exchange in the South Western Region to multi-metering was successfully completed in November, 1950, and details may be of interest.

The existing through-dialling scheme had not been designed for multi-metering and it was necessary to rearrange completely the existing dialling codes in use for single-fee and through dialling. Some 36 routes from selector levels, with a total of over 250 outgoing junctions, mostly to U.A.X.s, were involved. Second selector levels on 7 and 8, and third selector levels on 80 and 89 were in use on the existing scheme, and level 6 was, therefore, selected for multi-metering, with junctions routed from levels on second and third selectors. The method of change-over adopted was as follows:—

(1) Modify U.A.X. route-discriminating equipment to enable calls to be routed on either the old or new code during the transition stage. Modify cord circuits at manual exchanges and provide additional junctions for guarded metering routes.

(2) Complete new trunking and tee old and new levels together at Taunton.
(3) Advise all subscribers concerned of the new codes and transfer date.
(4) After change-over, modify U.A.X. route-discriminating equipment to cater for new codes only and connect N.U. tone to the old levels at Taunton.

To accommodate the additional codes (amounting to some 50 at each exchange) during the transition stage, common route-discriminating equipment was used at all U.A.X.s with direct routes to Taunton; discrimination was restricted to the last junction routing digit. Final modification after change-over permitted discrimination on the first subscriber's digit for nearly all codes.

The teeing was arranged simply on the I.D.F. by the provision of new permanent jumpers and twisting the old jumpers on the end of the new to facilitate recovery.

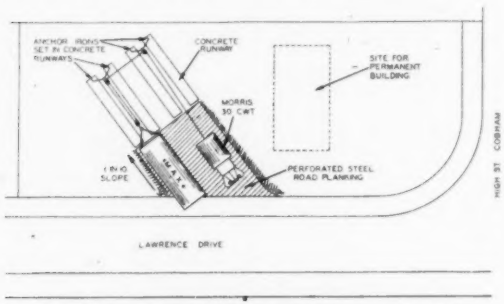
V. E. B.

London Telecommunications Region

CONVERSION OF COBHAM (KENT) C.B.S.2. EXCHANGE TO AUTOMATIC WORKING USING A MOBILE AUTOMATIC EXCHANGE

Early in December, 1950, the first mobile automatic exchange (M.A.X.) in the London Region was brought into service when the subscribers—138 in all—were transferred from the C.B.S.2 manual exchange in the local Post Office at Cobham (Kent) to a mobile automatic exchange (equivalent to a U.A.X. No. 13). The M.A.X. was used because of the need for quick conversion following notice given by the Sub-Postmaster to cease the manual exchange.

At Cobham the two vehicles containing the automatic equipment are located side by side towards the rear of the site for the permanent U.A.X. and clear of the proposed building



SITE PLAN SHOWING METHOD OF DRAWING-IN M.A.X.

position. Two sets of concrete runways 3 ft. wide by 24 ft. long were constructed to provide a good footing for the vehicles which may have to remain for some months. The ground level of the site was considerably higher than the adjoining roadway, and the trailers containing the M.A.X. equipment were pulled into position by means of pulley blocks and tackle. A normal 30-cwt. Morris vehicle provided the motive power. Ring bolts had been set at the end of the concrete runways to give a good fixing for the tackle. The weight of each equipped vehicle is about 8 tons.

It is interesting to note that the village of Cobham is renowned for its association with Charles Dickens, and it is reported that the Pickwick Papers were written in the local hostelry. The local inhabitants are very proud of their association with the past, and are keen to preserve the character of the village. The two M.A.X. vehicles are, however, quite inconspicious in their dark green paint, being set well back from the main street. A few hours after the opening a heavy snow storm laid a covering of white over everything and the Dickensian appearance of the village was complete.

S. M. E. R.

Scotland

RECOVERY OF NORTHERN UNDERGROUND CABLE

Recovery of the Northern underground cable is nearing completion in Scotland. When the contractor reaches Glasgow, he will have recovered 88·7 miles of cable in Scotland of a total weight of 1,730 tons. All this cable was transported to Reading by the Department's long-distance haulage fleet in well-planned operations. The Regional staff was responsible for removing the cable from the roadside and for temporary storage.

The cable was provided in 1905, and labels bearing the names of the workmen were found in many of the joints, including those on either side of the England-Scotland boundary. On the English side the label read as follows:—

"For Auld Lang Syne—the first and last joint in England.

"This joint was made by Fred Lofthouse, of Lancaster, assisted by John Latton, of Shap Beck, near Penrith, and was wiped and brazed by Joseph Hodpon, of Penrith, and was superintended by Robert Sharples, of Preston, on Wednesday, 13th day of September, 1905.

"In God we trust. God Save the King."

and on the Scottish side:—

"Should auld acquaintance be forgot and never brought to mind,

"Should auld acquaintance be forgot in the days of Auld Lang Syne.

"After a successful journey of 65 miles, done by R. Sharples' gang in less than 12 months, Jointer Clayton, of Birmingham, made the first joint on the Scotch side on Wednesday, 13th September, 1905.

"Plumber—J. Hodpon. Foreman—R. Sharples.

"God Save the King."

This work was done before cable jointers were stationed in Scotland and the men came from England. The brother of one is still with the Post Office in Scotland, and older members of the staff remember Foreman Sharples, but trace of the other men named has been lost.

The cable was in excellent condition after 45 years and was withdrawn without trouble, only a few short lengths having, so far, refused to move, due, it is thought, to unrecorded joints. The cast iron pipe is also in excellent condition, many sections showing no sign whatever of rust. An interesting feature is that, in spite of the extensive road widening which must have taken place in this main road, the pipe is still, mainly, in the grass verge.

The whole cable was an excellent job which did great credit to the Engineers who designed and constructed it. Only the change in transmission technique, rendering the make-up of the cable obsolete, prevented it giving many years of useful service.

Headquarters are now considering re-use of the pipe for a modern coaxial cable. In view of the extensive reconstruction planned for this road, it can hardly be expected that the pipe will remain as undisturbed as in the past 45 years.

G. J. F.

Junior Section Notes

Bishop's Stortford Centre

On the 15th November, 1950, practically our full membership attended a lecture on "Faraday Building," given by Mr. A. E. W. Lee, of Museum exchange. An excellent description of the layout of the building and the equipment therein was given, together with some astounding facts and figures. On the 22nd November, 1950, almost our full complement paid a visit to Faraday Building and saw all that our previous speaker had described—and more! We would like to express our sincere thanks to Mr. Knox, Liaison Officer, Home Counties Region, and the Cambridge Area Liaison Officer, Col. T. C. Loveday, who made the arrangements for this very interesting visit.

On 4th January, 1951, Mr. R. A. Collins gave a most instructive lecture on "Internal Combustion Engines," dealing mainly with the 2- and 4-stroke cycles, carburation and positioning of cylinders for engine balance; questions were answered both during and after his talk. Unfortunately, bad weather adversely affected the attendance at this meeting.

At the time of writing these notes the Centre was looking forward to the following programme:—

19th January, 1951.—A Film Show by the Central Office of Information.

22nd February, 1951.—Invitation from the Cambridge Centre to attend a lecture at Cambridge, given by Dr. Searle, late Professor of Physics at Cambridge University, on his personal contacts with the late Oliver Heaviside.

February, 1951.—Talk on Generation of Domestic and Industrial Power by an Engineer of the Eastern Electricity Board, followed at a later date in the same month by a visit to Brimsdown Power Station.

A creditable response is being made by our members to the Centre's activities, but more members, particularly external personnel, would be very welcome. G. E. D.

Chiltern Centre

The Annual General Meeting of the Chiltern Centre was held on Wednesday, 29th November, 1950, and officers for the coming year were elected as follows:—*Chairman*, Mr. F. J. Fagan; *Vice-Chairman*, Mr. F. Sherriff; *Secretary*, Mr. H. J. Trotman. Committee re-elected en bloc.

It is hoped to arrange a full programme for 1951, including film shows, a lecture by Mr. K. E. Felton (member), visits to local works and other activities. H. J. T.

Darlington Centre

On 21st November, 1950, a talk, "Domestic Radio" was given by one of our members, Mr. E. O. M. Grimshaw (of Electronic Organ fame) in his usual breezy style. A very lively discussion which followed, with the Telephone Manager (Colonel Sutcliffe) a participant, was thoroughly enjoyed. On reflection, this meeting could be voted as ideal both from the speaker's and his listeners' points of view.

Owing to the illness of Dr. Fothergill, in December, his talk on "Coloured Photography" could not be given and an interchange of programme arrangements was necessary. The talk was replaced by one on "Radar Up To Date," by Mr. R. R. Johnson, a contribution which was well received by his audience. Dr. Fothergill's talk will be given on 10th April, 1951.

"Where the Money Goes," was the title of a talk by Mr. K. Millard, given in January. This subject was certainly most enlightening—the disposal of the Budget Allocation of money to be expended in the Area by the Engineering Department gave the listeners the impression that the problem really must give a headache to those officers responsible. Mr. K. Millard proved to be a very able speaker.

Our meetings to date have been very well attended in spite of the incidence of 'flu., which accounted for the absence of some of our regulars.

On 25th January, several of the Centre members journeyed to Middlesbrough for the talk by a Darlington Centre member —Mr. B. V. Northall, on "Television." This was preceded by a very pleasing ceremony—the presentation by the C.R.E. (Mr. W. F. Smith) of his prize to Mr. R. V. Heppinstall for the best paper by a Centre member in the North Eastern Region and of the Shield to the Middlesbrough Centre to mark the success of one of its members. May the Darlington Centre record their sincere congratulations in these notes.

Needless to say, the Darlington Centre has now designs on that Shield! Hitherto, our Centre has refrained from entering the Competition due to written papers of talks by our members not being available. C. N. H.

Doncaster Centre

On Wednesday, 20th December, 1950, a most interesting paper was given to the above centre by Mr. E. C. Elstree-Wilson of York. The subject, "Wood Turning," was a rather unusual one, and Mr. Elstree-Wilson, who brought along his own lathe, soon captured his audience by inviting them individually to have a try during the course of his demonstration. At the conclusion the local secretary thanked Mr. Elstree-Wilson for the most interesting paper and demonstration we have yet received. J. I. L.

Guildford Centre

The Guildford Centre continues to grow in strength and now numbers 100. Great interest is being shown by the members in all activities, factory visits being particularly appreciated.

The Secretary, Mr. F. Kelsey, tendered his resignation and at a General Meeting on 3rd November, Mr. L. G. Wallis was elected Secretary and Mr. R. J. Nicholls Assistant Secretary.

The Winter Session was opened by Mr. H. Wells, Area Engineer, who gave a most interesting talk on "Sound Recording."

A party of 33 visited the factory of Pirelli General, Ltd., at Eastleigh, on 22nd November, and were shown the complete process of telephone cable manufacture from the copper ingot to the finished cable. On 14th December, Mr. W. Hancock of British Railways, gave a talk on "Railway Signalling."

The programme for 1951 was arranged as follows:—

17th January.—The Osram Lamp Works, Wembley. (Visit).
February.—Annual General Meeting.
28th February.—"Photography in the Post Office," by Mr. W. A. Paul. (Lecture).
6th March.—Harris Lebus, Ltd., Mass Production Furniture Factory. (Visit).
April.—Pirelli General Cable Works, Southampton. (Visit).
May.—Visit to a Coal Mine, Canterbury.

Other visits and lectures are in process of organisation and will be announced later. L. G. W.

London Centre

The London Centre has been very active recently. On the 14th December, 1950, over 60 members attended a most interesting lecture on "Electronic Switching" by Mr. T. Flowers, and this was followed, on 16th January, 1951, by "Some Aspects of Television" by Mr. T. Kilvington, the attendance of over 100 members being a great encouragement to the Centre Committee. An excellent tea was provided on both occasions. A pleasant ceremony was performed before Mr. Kilvington delivered his lecture, Mr. A. E. Penny, our Liaison Officer presenting a certificate and cheque for £3 3s. to Mr. Cochrane for his essay on "Precision Testing." Congratulations, Mr. Cochrane!

Are all members aware that Papers read at Junior Section Meetings are considered for the award of Institution prizes? The Judging Committee on Papers believe that if this is widely known more Papers will be forthcoming.. Now then, authors, produce those Papers and keep the Judging Committee busy.

Papers are not far removed from periodicals. It may surprise members to learn that at the time of writing no less than 1,611 periodicals are circulating within the London Centre. This figure does not include local purchases by Areas. If members wish to see more of these periodicals, increased speed in circulation is required please.

East Area have recently held an inter-exchange quiz between Ilford and Seven Kings groups. After 25 difficult questions per team, Ilford were declared victors, with 69 points against Seven Kings 45.

Many visits to places of interest in and around the capital have taken place. The following is an excerpt from a typical monthly report submitted to the Centre Committee :— Premises visited, Messrs. Tate & Lyle, Standard Telephones & Cables, B.B.C. Broadcasting House, Electrical and Musical Industries, South-East Gas Works, Belling Lee Electrical Products, Kodaks, British Oxygen, Merton Board Mills, and Vickers Armstrong.

Much is being done in the London Centre, and it is the intention of the Centre Committee to maintain the interest of all staff in the Junior Section. Come on London, keep your Area Committee on their toes ! M. J. G.

Leeds Centre

A belated start to the present Session was made with a visit to Kirkstall Power Station by kind permission of the B.E.A. The attendance of 26 was very gratifying considering that the centre has been dormant for three years. An inter-centre quiz with Bradford was arranged for February with further papers for March and April, and it is hoped that interest will be maintained to give a good send off to the new Session in September. E. G. S.

Middlesbrough Centre

On 16th November, 1950, a writter paper was given by Mr. R. R. Johnson, Vice-Secretary, entitled " Radar." A short film on the subject preceded this paper.

Mr. C. Allison gave his talk on " Electricity in the Home and Workshop," in December, and has since left Middlesbrough Area to take up duties at Leeds. Mr. D. Paterson, our Chairman, thanked Mr. Allison for all his good work during his term of office as Vice-Chairman, and expressed good wishes on behalf of the Middlesbrough Centre for success in his new position.

25th January, 1951, marked a special occasion, when we were honoured by the visit of Mr. W. F. Smith, Chief Regional Engineer, and Mr. A. C. Holmes, Regional Liaison Officer, for the presentation of the Chief Regional Engineer's Book Prize for the best Paper submitted in the Regional Contest, to Mr. R. V. Heppinstall, for his paper entitled " Local Line Planning." The Chief Regional Engineer's Presentation Shield, which accompanied the Book Prize, was received by the Chairman on behalf of the Middlesbrough Centre.

Courtesy of North Eastern Evening Gazette Ltd.

PRESENTATION OF THE C.R.E.'s SHIELD TO MIDDLESBROUGH CENTRE. *Reading from left to right are* Mr. A. C. Pitcairn (Area Engineer), Mr. D. Paterson (Chairman), Mr. R. V. Heppinstall, Mr. J. S. Gill (Area Liaison Officer), Mr. B. V. Northall, Mr. W. F. Smith (C.R.E.), Mr. J. Brown (Secretary).

The presentation was followed by a talk on " Television," by Mr. B. V. Northall, one of our Darlington colleagues, the talk being illustrated with the aid of a film strip. We were pleased to welcome eight Darlington members, the Telephone Manager and the Area Engineer, with several other Senior Members and ten members of the Tees-Side and District Amateur Radio Club. In addition, 40 of our own members attended.

At the time of writing, our next meeting was to take place on 22nd February, 1951, with Mr. R. Dingwall, M.I.E.E., of Messrs. Dorman, Long & Co., Ltd., lecturing on " Electrical Engineering in Iron and Steel Works." This was to be followed on 13th March, 1951, by a " Two-Way Quiz," between Darlington and Middlesbrough Centres.

Sheffield Centre

The 1950/51 Session found our membership strength well over the 80 mark, and the first visit, which was to the Sheffield Transport Repair Depot, was very well attended. Since then, however, members have not attended the meetings so well as was expected. Amongst the features of the programme have been :—

August.—Visit to Sheffield Fire Station.

September.—Visit to United Steels, Ltd., Stocksbridge.

October.—Lecture—" Precision Testing of Underground Cables," by Mr. G. Wilshaw.

November.—Visit to Firth Brown's Melting Shops.

December.—" Post-War Motor Racing," by Mr. T. C. Harrison.

At the time of writing, we are again joining with the local Student Section of the I.E.E. to hold a Dance towards the end of March and hope that it will meet with the same success as last year's event.

There is still a complete absence of Youths-in-Training from the attendance at meetings. We can offer no explanation but we do hope that eventually a little enthusiasm will be shown by that section of the staff. The External members, it is pleasing to record, are very keen.

To round off the year's activities other features before the A.G.M. arranged for April were to be a lecture on " Television" and a visit to the local newspaper offices.

A letter has been drawn up by our Chairman and, with the Committee's approval, will be sent to all members in an effort to provide a future programme in the coming 1951/52 Session to suit all tastes. G. F.

York Centre

The 1950/51 Session opened on 12th October, 1950, with a paper by Mr. G. Dale of Darlington, entitled " U.A.X. Simplified." Since then, we have had the following papers :—

" Organisation and Function of the Telephone Manager's Office," by Mr. H. A. Clibbon, A.M.I.E.E.

" Television," by Mr. C. Buckle.

" Have you Seen These ? " by Mr. J. P. Allen, of Regional Training School, Harrogate.

February.—" 200-line P.A.B.X.," by Mr. C. S. Mills.

March.—" Rectifiers and their uses," by Mr. B. B. Watt.

On the 16th November, 1950, a party visited the British Railway Signal Section and were conducted on a most interesting tour of the new Colour Light Signal Equipment by Mr. G. G. Halliwell.

On the 1st December, 1950, a dinner/smoker was held at the Davy Hall Restaurant. A most enjoyable evening was spent by both members and guests.

In conclusion, we take great pride in announcing Mr. W. N. Pallier's success in the National Competition for the best Junior Section Paper. On 2nd January, he was presented with a cheque and certificate at a Senior Section Meeting at Leeds, for his Paper, " Telegraph Automatic Switching System."

J. P.

Book Reviews

"Quartz Vibrators." P. Vigoureux, D.Sc., and C. F. Booth, O.B.E., M.I.E.E. H.M. Stationery Office. 371 pp. 30s.

There are many minor and often curious phenomena associated with electricity and magnetism which have been known for a considerable time but which have found little or no practical application. Among these are the Kerr, Peltier, Kundt and Zeeman effects, the electro-capillary phenomena, pyro-electricity and many others.

Up to about 30 years ago, these would have included the piezo-electric effect whereby certain dielectrics of crystalline nature exhibit signs of electrification when mechanically deformed and conversely are deformed mechanically when subjected to electric stress. The effect is present in varying degrees in many kinds of crystal both inorganic and organic, but the most important is quartz or natural rock crystal which is a form of silicon oxide. Although the piezo-electric effect in quartz is weak compared with some other substances quartz itself is highly elastic and when a piece of quartz rod or plate is set into mechanical vibration the vibration persists for an appreciable time because of the small internal loss. Quartz is thus an ideal material for a mechanical resonator and the piezo-electric effect provides a means of coupling such a vibrator to an electric circuit where it behaves as an electrically resonant circuit of extremely low loss.

The piezo-electric qualities in quartz only became important when the thermionic valve was invented and its first important application was in connection with submarine echo sounding, where it was used to impart mechanical energy to the water and also to convert the weak returning echo into an electrical signal.

In recent years a most important development has been the use of quartz resonators to control the frequency of valve oscillators and at a later date as components in electric filters. Workers in many countries have made important contributions to knowledge both in the preparation of the crystals and in their application, and it is gratifying to know that this country has been well to the fore in this respect.

Much of the early work in this country on the properties of piezo-electric quartz resonators was carried out by the late Dr. D. W. Dye of the National Physical Laboratory, and after his death this work, which was of outstanding and fundamental character, was continued by his colleagues among whom was Dr. Vigoureux, one of the authors of the present work. Dr. Vigoureux subsequently was commissioned by the Radio Research Board of the Department of Scientific and Industrial Research to produce a survey of current knowledge on "Quartz Oscillators and Resonators," and a second edition was published in 1939. The advances which have been made since then in the manufacture and in the use of quartz resonators, and the increasing importance of the place they occupy in telecommunications made a revision of this earlier edition necessary, and it was decided by the Board that the revision should include in addition to the theoretical treatment more detailed information on the manufacture, application and performance of quartz vibrators. In this revision, therefore, Capt. C. F. Booth, O.B.E., Staff Engineer of the Radio Experimental Branch of the Post Office Engineering Department, was invited to collaborate with Dr. Vigoureux.

Capt. Booth's experience and knowledge of the production of quartz resonators has made him admirably fitted to assist in this revision. About 25 years ago, the Post Office radio engineers were building short-wave radio telephone senders and encountered considerable trouble in holding the frequency of the sender steady during modulation. As a result, it was found necessary to generate the carrier frequency by amplifying harmonics of a quartz-controlled oscillator. At that time there was no very satisfactory source of prepared crystals in the country, and it was necessary to import them. This was unsatisfactory, as crystals had often to be adjusted to suit the oscillator circuits and in the end it became necessary to acquire the technique of cutting and lapping crystals in the radio laboratories. This work was started by a small team under Capt. Booth, and it has continued under his control until to-day. Capt. Booth's work has led to the production of quartz crystals of the highest precision and stability which have been used, not only for purposes of telecommunications, but also for the provision of standards of frequency and for the measurement of time. The work of Capt. Booth and his colleagues has been valuable, not only to the Post Office but also to the Fighting Services and the B.B.C. Furthermore, the time-keeping qualities of electric clocks driven by quartz-controlled oscillators is so much better than the best mechanical clocks that a few years ago the Astronomer Royal installed in the Royal Observatory a number of quartz-controlled clocks for determining standard time.

The earlier chapters of the book deal with the properties of quartz, the occurrence and examination of quartz crystals, the piezo-electric phenomenon in quartz, the theory of the quartz resonator, the valve-maintained quartz oscillator and the various types of quartz vibrator. Then follow chapters dealing with the practical use and practical applications of quartz resonators, starting with the mounting of vibrators—the specification and testing of elements, the ageing phenomena of quartz elements, temperature control and frequency standardisation, frequency control of radio transmitters, carrier generation for multi-channel carrier systems, luminous resonators, frequency selection, ultrasonics and miscellaneous applications.

The next three chapters are devoted to descriptions of the various manufacturing processes, starting with the selection of the natural crystal, cutting, lapping and etching, plating, mounting, adjusting and testing. The design of plant for the production of resonators is next considered and the description of a typical layout of a factory for this purpose is given.

A final chapter deals with the future developments and here the authors deal with alternatives to quartz and the possibilities of growing suitable quartz crystals artificially. Other matters dealt with are artificially produced alternatives to quartz for certain classes of resonators and future possible developments in frequency standards.

Apart from the section on production, much of the information has previously appeared in articles and papers presented by the authors and others before learned societies, but the fact that both authors are thoroughly versed in the subject has enabled them to make a wise and appropriate selection of subject matter and, in consequence, this book can be regarded as probably the most up-to-date and authoritative work on the subject. It is well illustrated by drawings, diagrams and an excellent series of plates and is completed by a comprehensive bibiography of British and foreign literature on the subject and a useful index.

For a Government publication the price is rather high, but by present-day standards it is excellent value for money.

A. J. G.

"Signal Venture." Brig. L. H. Harris, C.B.E., T.D., M.Sc., M.I.E.E. Gale & Polden Ltd. 267 pp. 22 ill. 18s.

This is an autobiography with a Signals theme. The author went to Australia in 1914, at the age of 17, to learn farming and served during the 1914-18 War with the Australian Signals in the Middle East and France. Between the wars, as an engineer of the Post Office, he kept in touch with Signals as a Territorial Army Officer with the 44th Divisional Signals. During the 1939-45 War he served with the B.E.F., leaving France via Dunkirk, planned the communications for the landing in 1944 and went through the campaign as Chief, Telecommunications Section, SHAEF.

As a corporal with the Australian forces he laid D8 with the six-horse-drawn cable wagon and as a Brigadier planned the communications using the latest technique of carrier telephony on coaxial cables. The result is a most instructive book for all telecommunication engineers, be they civilians or regular or territorial officers. But the book has a wider appeal. The author has a seeing eye, has mixed with all types and can bring to vivid life both scenes and persons. He has also a nice discrimination in leaving unsaid those things which, after all, are best forgotten. There is no petty criticism, no backstairs "secrets."

The fresh air of the Australian farm and the pioneering spirit which took the author there are in evidence up to the last chapter. The only criticism I have is that the result does not make a good bedside book. I lost sleep over it—and enjoyed every page.

As a postscript may I add that my wife is doing likewise.

J. R.

Staff Changes

Promotions

Name	Region	Date
Sen. Exec. Engr. to Asst. St. Engr.		
Taylor, F. J. D.	E.-in-C.O.	5.12.50
Seaman, E. C. H.	E.-in-C.O.	18.2.51
Sen. Exec. Engr. to P. Sc. Offr.		
Scowen, J.	E.-in-C.O.	28.12.50
Area Engr. to Dep. T.M.		
Markby, E. J.	L.T. Reg.	16.12.50
Exec. Engr. to Sen. Exec. Engr.		
Green, R. G.	N.W. Reg.	1.1.51
Wilkinson, E. H.	N.E. Reg. to N.Ire. Reg.	1.1.51
Arnold, C. W.	E.-in-C.O.	1.1.51
Goldsmith, F. H.	Scot. to E.-in-C.O.	6.12.50
Holliday, R. F.	L.T. Reg.	8.1.51
Woodhead, H. C.	E.-in-C.O.	1.1.51
Asst. Engr. to Exec. Engr.		
Giles, F. R.	E.-in-C.O.	12.12.50
Campbell, K. W.	E.-in-C.O.	12.12.50
Streeter, A. R.	E.-in-C.O.	1.1.51
Hall, G. W.	S.W. Reg.	1.1.51
Robinson, R. T.	L.P. Reg.	8.1.51
Clark, E. A.	N.E. Reg.	31.12.50
Yates, G. A.	Mid. Reg.	27.1.51
Wallace, K. C.	N.W. Reg.	27.1.51
Barron, H.	N.W. Reg.	4.2.51
Tech. Offr. to Asst. Engr.		
Davies, A. P.	E.-in-C.O.	13.1.51
Harrison, C. C.	E.-in-C.O.	13.1.51
Roberts, E.	W.B.C. Reg. to E.-in-C.O.	13.1.51
Tech. Offr. to Asst. Engr.—continued.		
Campbell, A. I.	Scot. to E.-in-C.O.	20.1.51
Gee, J. A.	N.W. Reg. to E.-in-C.O.	13.1.51
Fernie, G. B.	Scot. to E.-in-C.O.	20.1.51
King, F. A.	E.-in-C.O.	13.1.51
Wilsdon, H. F.	Scot. to E.-in-C.O.	13.1.51
Sixsmith, J.	E.-in-C.O.	13.1.51
Hall, R.	N.W. Reg. to E.-in-C.O.	13.1.51
Cruikshanks, H. K.	Scot. to E.-in-C.O.	13.1.51
Hilton, C. G.	N.W. Reg. to E.-in-C.O.	13.1.51
Pullen, A. E.	E.-in-C.O.	13.1.51
Davis, Eduard	E.-in-C.O.	13.1.51
Kershaw, R. J.	N.W. Reg. to E.-in-C.O.	13.1.51
O'dell, S. H. G.	H.C. Reg. to E.-in-C.O.	13.1.51
Cumming, W. S.	Scot. to E.-in-C.O.	20.1.51
Roberts, S.	N.W. Reg. to E.-in-C.O.	27.1.51
Richardson, G. E.	N.E. Reg. to E.-in-C.O.	13.1.51
Francois, R. A.	L.T. Reg. to E.-in-C.O.	13.1.51
Crawford, A.	Scot. to E.-in-C.O.	13.1.51
Kelson, D.	Mid. Reg. to E.-in-C.O.	13.1.51
England, H. S.	E.-in-C.O.	13.1.51
Hearnden, A. H.	E.-in-C.O.	13.1.51
Tomlin, V.	H.C. Reg. to E.-in-C.O.	13.1.51
Shannon, W. N.	Scot. to E.-in-C.O.	13.1.51
Grandison, D. O.	S.W. Reg. to E.-in-C.O.	13.1.51
Russell, P. S.	Scot. to E.-in-C.O.	13.1.51
Harrison, C. J.	Mid. Reg. to E.-in-C.O.	13.1.51
Godliman, D. C.	E.-in-C.O.	13.1.51
Moody, J. W.	L.T. Reg. to E.-in-C.O.	13.1.51
Weller, W. F. E.	L.T. Reg. to E.-in-C.O.	13.1.51
Hayton, F.	N.W. Reg. to E.-in-C.O.	13.1.51
Adams, G. W.	L.T. Reg. to E.-in-C.O.	13.1.51
Fowkes, G. E.	N.E. Reg. to E.-in-C.O.	13.1.51
Vogan, D. H.	L.T. Reg. to E.-in-C.O.	13.1.51
Harvey, F. J.	L.T. Reg. to E.-in-C.O.	20.1.51

Transfers

Name	Region	Date
Sen. Exec. Engr.		
Jeynes, E. H.	L.T. Reg. to S.W. Reg.	8.1.51
Harper, S. D.	E.-in-C.O. to Admiralty	8.1.51
Exec. Engr.		
Murray, J. B.	E.-in-C.O. to Air Ministry	1.12.50
Hayes, C. R.	L.P. Reg. to Air Ministry	1.12.50
Barnsdall, S. G. W.	E.-in-C.O. to S.W. Reg.	4.12.50
Roberts, W. J.	E.-in-C.O. to W.B.C. Reg.	28.12.50
Perkins, J. J.	E.-in-C.O. to N.E. Reg.	18.12.50
Brown, W. D.	L.T. Reg. to E.-in-C.O.	1.1.51
Asst. Engr.		
Harris, F. L.	E.-in-C.O. to I.T.D.	11.12.50
Stretton, J. A.	E.-in-C.O. to P. & T. Dept., Eritrea	16.12.50
Fairhurst, H. J.	E.-in-C.O. to N.W. Reg. (reverted to T.O.)	27.12.50
Masdin, R. M.	E.-in-C.O. to H.C. Reg.	15.1.51
Harris, T.	L.T. Reg. to E.-in-C.O.	1.1.51
James, R. H.	E.-in-C.O. to Min. of Civil Aviation	8.1.51
Asst. Engr.—continued.		
Leask, D. R.	E.-in-C.O. to Scot.	22.1.51
Shaw, S.	W.B.C. Reg. to E.-in-C.O.	7.1.51
Heesom, S. D.	E.-in-C.O. to Min. of Civil Aviation	15.1.51
Howcroft, F. W.	E.-in-C.O. to Admiralty	1.2.51
Hales, J. T.	E.-in-C.O. to Admiralty	1.2.51
Balls, R. W.	E.-in-C.O. to H.C.R. (reverted to Tech. IIA)	5.2.51
Carter, P. E.	E.-in-C.O. to L.T. Reg.	12.2.51
Cook, R. B.	L.T. Reg. to E.-in-C.O.	12.2.51
Tribe, D.	E.-in-C.O. to L.T. Reg.	19.2.51
Cullis, A. D. S.	L.T. Reg. to E.-in-C.O.	19.2.51
Tungate, R. G.	E.-in-C.O. to Mid. Reg.	25.2.51
Exper. Offr.		
Hayward, G. O.	E.-in-C.O. to P. & T. Dept., Gold Coast	15.2.51
Asst. Exp. Offr.		
Orchin, D. I. W.	E.-in-C.O. to Admiralty	22.1.51

Deaths

Name	Region	Date
Chief Reg. Engineer		
Morgan, J.	W. & B.C. Reg.	12.1.51
Exec. Engr.		
Marchant, H. J.	E.-in-C.O.	27.12.50
Asst. Engr.		
Pinfield, E.	Mid. Reg.	26.11.50
Reeve, C. W.	E.-in-C.O.	16.12.50
Ruck, A. A.	L.T. Reg.	2.2.51
Inspector		
Cox, R. D.	N.W. Reg.	2.12.50
Brown, S. C. G.	L.T. Reg.	20.1.51
Headen, S. A.	L.T. Reg.	28.2.51
Tech. Asst.		
Clephane, H.	E.-in-C.O.	11.12.50

Retirements

Name	Region	Date
Sen. Exec. Engr.		
Worthington, C. E.	N.Ire. Reg.	31.12.50
Mayman, A. C.	E.-in-C.O.	31.12.50
Barrington, R. N.	E.-in-C.O.	31.12.50
Area Engr.		
Pearson, S. G.	N.W. Reg.	31.12.50
Tamplin, G. R.	S.W. Reg. (voluntary retirement)	7.1.51
Exec. Engr.		
Tough, J. D.*	S.W. Reg.	23.10.50
Cawthra, W. A.	E.-in-C.O. (Resigned)	11.12.50
Talbot, H. J.	L.T. Reg.	31.12.50
Strong, H. A.	Mid. Reg.	31.12.50
Ashton, H.	N.W. Reg.	31.12.50
Harris, S. R.	S.W. Reg.	31.12.50
Foulgar, E.	W.B.C. Reg.	31.12.50
Evans, C. E.	W.B.C. Reg.	25.1.51
Matthews, W.	L.T. Reg.	28.2.51
McDougall, R.	Scot.	28.2.51
Asst. Engr.		
Parkinson, R. N.	L.T. Reg. (Resigned)	3.10.50
Whitehead, D. J.	E.-in-C.O. (Resigned)	30.12.50
Cox, C. R.	N.W. Reg.	31.12.50
McKinnon, N.	Scot.	31.12.50
Foy, E. P.	Scot.	31.12.50
Whitaker, P.	Mid Reg. (Resigned)	21.12.50
Channon, C. G.	E.-in-C.O.	15.1.51
Inspector		
Scott, J. S.	Scot.	31.12.50
Marshall, E. H.	Mid. Reg.	9.5.51
Headen, S. A.	L.T. Reg.	28.2.51
Banks, T. B.	Scot.	28.1.51
Tech. Assistant		
Doe, F. J.	E.-in-C.O.	14.2.51
Williams, A. J. F.	L.T. Reg.	23.2.51

**Incorrectly shown under Resignations in January 1951 issue.*

CLERICAL GRADES

Promotions

Name	Region	Date
H.E.O. to S.E.O.		
Nelson, W. J.	E.-in-C.O.	2.12.50
C.O. to E.O.		
Fisher, M. E. (Mrs.)	E.-in-C.O.	15.10.50
Thomson, C.	E.-in-C.O.	11.12.50

Retirements

Name	Region	Date
E.O.		
Taylor, W. G.	E.-in-C.O.	31.12.50
E.O.—continued.		
Brewer, T. D.	E.-in-C.O.	31.12.51

DRAUGHTSMEN

Retirements

Name	Region	Date
L./Draughtsman		
Parsons, C. W.	H.C. Reg.	31.1.51
L./Draughtsman—continued.		
Hale, F.	N.W. Reg.	26.1.51

Book Reviews

"Ordinary Non-Linear Differential Equations in Engineering and Physical Sciences." N. W. McLachlan, D.Sc.(Eng.). Oxford University Press. 201 pp. 89 ill. 21s.

Practically all the classical mathematical physics has evolved from the hypothesis of linearity which embodies the principle of superposition. When this principle is valid for a physical problem, the descriptive differential equations are linear, and an engineer can obtain solutions by well-known methods based upon the hypothesis of linearity. But the principle often fails to accord with the requirements of modern problems; consequently, descriptive equations are often non-linear and the ingenious solutions which have grown from the hypothesis of linearity are practically valueless, or, at the best, only poor and inadequate approximations. In this book, Dr. McLachlan sets out to provide engineers with a practical introduction to methods of solving ordinary non-linear differential equations.

Owing to the absence of a general mathematical theory of non-linear equations, Dr. McLachlan has concentrated on the presentation of particular analytical methods used in the solution of important technical problems. Some of the topics treated are: oscillations in electric circuits with non-linear elements; transient surges in hydro-electric installations; mechanical systems having non-linear control and non-linear damping; stability of synchronous electrical motors; relaxation oscillations and thermionic valve oscillators; frequency modulation in sound reproduction systems and the stability of ships. Thus, the book is not an analytical treatise with technical applications, but shows how certain types of non-linear problem may be solved, and how experimental results may be interpreted by non-linear analysis. A certain amount of new material is included to fill gaps in previous knowledge: there is a discussion of graphical and numerical methods of solution applied to non-linear equations with periodic coefficients.

Dr. McLachlan is to be congratulated on producing such an excellent work: this useful and long-needed volume can be warmly recommended to any engineering research worker or advanced student. H. J. J.

"Electronic Engineering Master Index, 1947-1948." 339 pp. 139s. 6d., and "Electronic Engineering Master Index, 1949." 296 pp. 125s. Electronics Research Publishing Co., Inc., New York.

These editions are the third and fourth volumes in the series. The 1947-48 edition contains more than 18,000 references to electronic and allied engineering literature printed throughout the world during 1947 and 1948, including 5,500 electronic and allied patents issued by the U.S. Patent Office during these two years. The 1949 edition likewise contains more than 12,000 references to literature (including 4,000 U.S. patents) printed during 1949. The references have been taken from the major international scientific magazines, journals and proceedings, from electronic and allied patents issued by the U.S. Patent Office, and from declassified documents published by the U.S., British and Canadian Governments. The 1949 edition also contains references to British and American reports on German and Japanese research developments, as well as many theses on electronic subjects submitted at major American universities.

The references are classified under subject headings, and the patents are listed separately in numerical sequence under each heading. A cumulative cross-index at the end of each book serves as a useful guide to that book and also to the previous editions. Five or six pages in each book are devoted to a Bibliography of Engineering Books in which are listed the books published in the U.S. during the periods covered, as well as a few published in other countries.

The books should find a place in the reference library of every electronic engineer, and should prove invaluable to anyone who has occasion to search for electronic literature. D. C. G.

BOARD OF EDITORS

H. Faulkner, C.M.G., B.Sc., M.I.E.E., Chairman.
F. E. Nancarrow, O.B.E., A.R.C.Sc., M.I.E.E.
A. H. Mumford, O.B.E., B.Sc.(Eng.), M.I.E.E.
W. T. Gemmell, A.C.G.I., B.Sc., M.I.Mech.E., A.M.I.E.E.
W. West, B.A., M.I.E.E.
D. A. Barron, M.Sc., A.M.I.E.E.
L. Chant.
C. E. Moffatt, A.C.G.I., Wh. Ex., A.M.I.E.E.
G. E. Styles, A.M.I.E.E., Managing Editor.
W. A. Humphries, A.M.I.E.E. | Assistant Editors.
J. P. Harding, B.Sc.(Eng.), A.M.Inst.C.E., A.M.I.E.E. | Assistant Editors.
A. J. Hutchison, Secretary-Treasurer.

Copyright

The entire contents of this Journal are covered by general copyright, and special permission is necessary for reprinting long extracts, but Editors are welcome to use not more than one-third of any article, provided credit is given at the beginning or end thus: "From the *Post Office Electrical Engineers' Journal*."

The Board of Editors is not responsible for the statements made or the opinions expressed in any of the articles in this Journal, unless such statement is made specifically by the Board.

Communications

All communications should be addressed to the Managing Editor, *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Telephone: HEAdquarters 1234.

Remittances should be made payable to "*The P.O.E.E. Journal*" and should be crossed "& Co."

Binding Cases

Cases for binding are available, and may be obtained from the Local Agents for 2s. Subscribers can have their copies of volumes bound, at a cost of 7s. 6d., by sending the complete set of parts to the Local Agents or to the *P.O.E.E. Journal*, Engineer-in-Chief's Office, Alder House, Aldersgate Street, London, E.C.1. Orders for binding for Vols. 1-19 should indicate whether the original binding case with black lettering, or the later pattern with gold, is required. Cases with gold lettering are the only type stocked from Vol. 20 onwards.

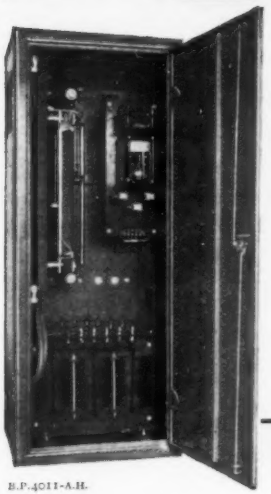
Back Numbers

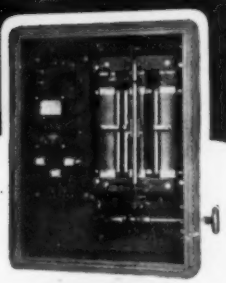
The price of the Journal, which is published quarterly, is 1s. 6d. (1s. 9d. post free) per copy, or 7s. per annum post free. Back numbers can be supplied, subject to availability of stocks, at 1s. 6d. each (1s. 9d. post free). Orders for back numbers may be sent to the Local Agents or to the Publishers.

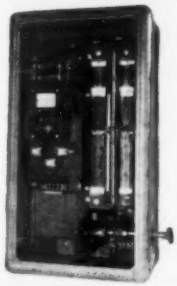
Advertisements

All communications relating to space reservations should be addressed to the Advertisement Editor, *P.O.E.E. Journal*, Alder House, Aldersgate Street, London, E.C.1. Communications regarding advertisement copy, proofs, etc., should be addressed to the Publishers, Messrs. Birch & Whittington (Prop. Dorling & Co. [Epsom], Ltd.), 49 Upper High Street, Epsom, Surrey.

AUTOMATIC VOLTAGE REGULATORS by B.P.T







Maintaining a constant voltage unaffected by variation in the supply voltage, frequency, load and load power factor is a problem which can be solved by the aid of our standard range of Automatic Voltage Regulators. For single phase operation there are 11 models from 12½ to 240 amps, for three-phase there are 13 models from 7½ to 150 amps.

Three typical models are illustrated from our standard range of wall or floor mounting types.

TOP 3-phase, air cooled, wall mounting model. Input 440V ± 10%, output 440V ± 1%. 7½ amps.

LEFT 3-phase, air cooled, floor mounting (cubicle) model. Input 440V ± 10%, output 440V ± 1%. 40 amps.

RIGHT Single-phase, air cooled, wall mounting model. Input 250V ± 15%, output 250V ± 1%. 25 amps.

Please write for further information and literature. BP401 9

BRITISH POWER TRANSFORMER CO. LTD.

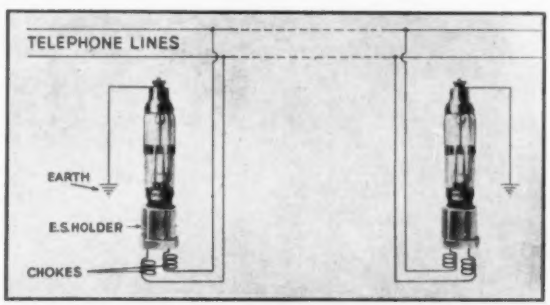
Phone: HOWard 1492 **QUEENSWAY, PONDERS END, MIDDLESEX** Grams: "Vitrohm Enfield"

B.P.4011-A.H.

EDISWAN Telephone Line Protectors

FOR THE PROTECTION OF LINES OF COMMUNICATION FROM SURGES INDUCED BY LIGHTNING OR FAULTS ON NEIGHBOURING POWER LINES

Ediswan Telephone Line Protectors have now been in commission for nearly twenty years. They have proved their worth in all parts of the world and are being called for and installed in ever increasing numbers. Many thousands were employed during the war years for the protection of vital lines of communication and were eminently successful. Reports of their outstanding merit and successful operation continue to reach us and in recent years they have proved of particular interest for protection against surges caused by lightning discharges.



Continued research has enabled us to patent a further improvement which removes any suggestion of delay in operation.

Further information and prices on application.

THE EDISON SWAN ELECTRIC CO. LTD., 155 CHARING CROSS ROAD, LONDON, W.C.2

Member of the A.E.I. Group of Companies

TE3

A New

Type L

CLIP-ON AMMETER

Specially designed for use with porcelain clad fuses and heavy duty conductors up to 4" diameter.

Fully insulated core

7 RANGES

0 — 10
0 — 25
0 — 50
0 — 100
0 — 250
0 — 500
0 — 1000
Amperes A.C.

FERRANTI

FERRANTI LTD. HOLLINWOOD LANCS.
LONDON OFFICE KERN HOUSE KINGSWAY W.C.2

F1 906

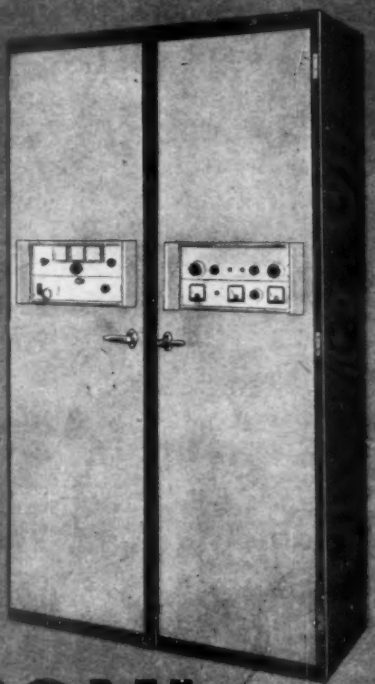
ELECTRICAL MEASURING INSTRUMENTS OF THE HIGHER GRADES

ERNEST TURNER ELECTRICAL INSTRUMENTS LTD.
CHILTERN WORKS, TOTTERIDGE AVENUE, HIGH WYCOMBE, BUCKS.
Telephone : High Wycombe 1301/2 *Telegrams : Gorgeous, High Wycombe*

HR 91 RECEIVER

A pre-tuned or continuously variable double super-heterodyne International Class Telegraph Receiver, range 3-27.5 Mc/s.

- Immediate selection of one of three channels.
- Double Diversity reception with electronic path selection.
- Provision for High Speed C.W. On/Off or F.S.K. reception.
- Self-contained for 200-250V. 50-60 c/s A.C. Supply.
- Automatic frequency control.



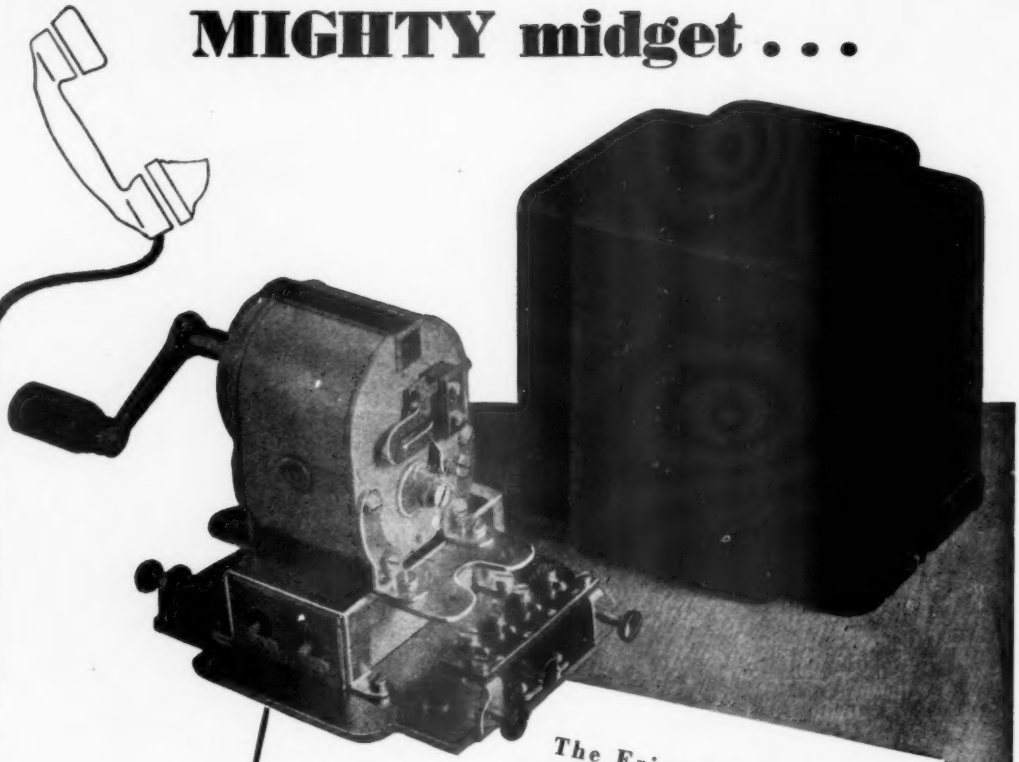
MARCONI

COMMUNICATION SYSTEMS

SURVEYED · PLANNED
INSTALLED · MAINTAINED

MARCONI'S WIRELESS TELEGRAPH CO. LTD., MARCONI HOUSE, CHELMSFORD, ESSEX

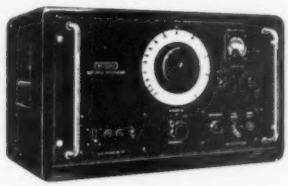
MIGHTY midget . . .



The Ericsson **ALNICO GENERATOR** illustrated is a robust yet elegant example of Ericsson practice. Has an output equivalent to the old 4-Bar unit but is less than half its size and weight. Certified safe for use in mines, and can be supplied unmounted or without the moulded bakelite case. Our heavy duty **ALNICO** generator is slightly larger but uses the same case.

THE Ericsson ALNICO GENERATOR

ERICSSON TELEPHONES LTD. · *Head Office:* 22 LINCOLN'S INN FIELDS, LONDON, W.C.2. · *Tel:* HOL. 6936
Works: BEESTON, NOTTS.



A STANDARD SIGNAL SOURCE for THE AUDIO FREQUENCY BAND

THE R.C. Oscillator Type D-330 gives a wide range of known levels into a 600-ohm load at any frequency from 20 c/s to 20 kc/s.

BRIEF SPECIFICATION

FREQUENCY: 20 c/s—20 kc/s.
ACCURACY: ± 1% or better.
OUTPUT LEVEL: 1W or 10mW into 600 ohms, selected by means of a switch.
ATTENUATORS: 7 steps of 10 db plus 12 db continuously variable.
HARMONICS: 1·75% total at 1W above 40 c/s. 1·0% total at 10 mW above 40 c/s.
HUM LEVEL: 50 db below output level.
DIMENSIONS: 20¼-in x 12¼-in x 11-in bench mounting — can be supplied for 19-in rack mounting if required.

Post this coupon
BY PASTING ON A POSTCARD

MUIRHEAD & CO. LTD · BECKENHAM · KENT · ENGLAND
Please send me Bulletin B-614 fully describing the R.C. Oscillator advertised in 'The Post Office Electrical Engineers' Journal'.

NAME .....

ADDRESS .....

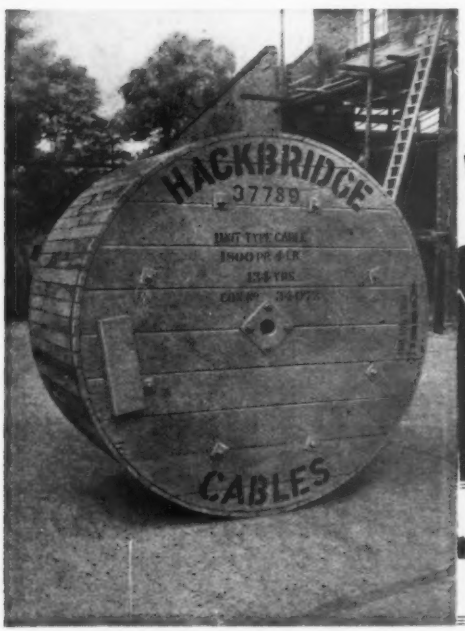
.....

.....

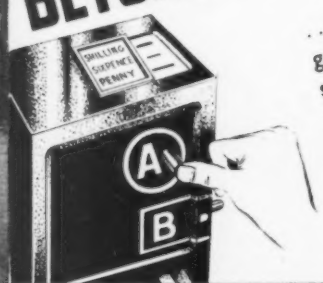
MUIRHEAD & CO., LTD.
PRECISION ELECTRICAL INSTRUMENT MAKERS
BECKENHAM·KENT·ENGLAND
Phone: BECkenham 0041 Telegrams & Cables: MUIRHEADS ELMERS-END

PRECISION MUIRHEAD ELECTRICAL INSTRUMENTS

MU. 24.



BEYOND THE BUTTON....

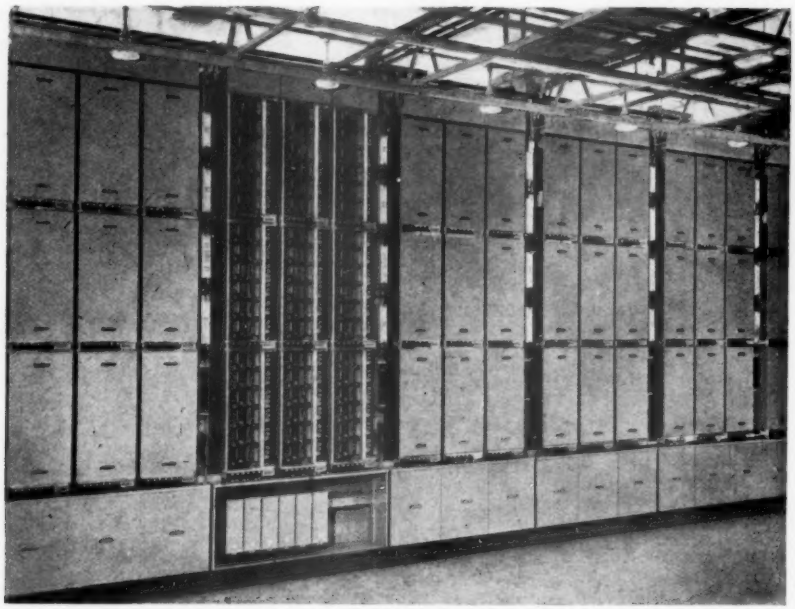


.... Hackbridge underground dry-core air-space lead covered and armoured cable.

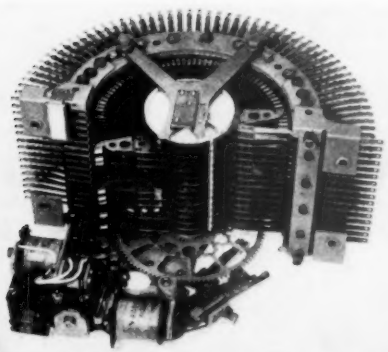
Contractors to G.P.O., British Railways, British and Colonial Government Departments.

HACKBRIDGE *Cable Company Limited*
KELVIN WORKS, HACKBRIDGE, SURREY
In Association with Bryce Electric Construction Company Ltd.
Branches at:
Birmingham, Bristol, Cardiff, Manchester, Newcastle, Sheffield

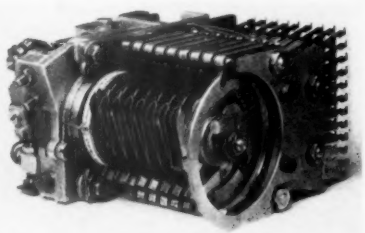
The Manitoba Telephone



Suite of Final Selector Racks with covers removed on one rack.



The High-Speed Motor Uniselector which operates at 200 outlets per second.



The Digit Switch developed specially for this system.

Administration LEADS THE WAY

at FORT ROUGE Winnipeg

SIEMENS Nº 17 M·A·X SWITCHING EQUIPMENT

This System has Selectors controlled directly from the Dial, with covered racks and apparatus of outstanding simplicity and reliability.

Special features of the system include:

- A switch fault liability barely exceeding that of a relay, achieved largely by eliminating mechanically-operated springsets.
- Complete elimination of all wiper cordage.
- Twin contacts on wipers and banks as well as on relays.
- Easy access to all wiring points including the multiple.
- Ability to match outlet availability to traffic loading.

These features, coupled with simple circuit and trunking arrangements, set a new standard in low maintenance costs.

Exchanges are also in hand for British Columbia, Australia, Southern Rhodesia and elsewhere.

SIEMENS BROTHERS & CO., LIMITED
WOOLWICH · LONDON · S.E.18.

MODERN CAPACITOR ENGINEERING

DUBILIER
CAPACITORS

Dubilier provide the most comprehensive range of Capacitors available today for Radio Transmitting and Receiving, in addition to Capacitors for Electronic and Industrial engineering.

Dubilier Capacitors are designed and manufactured to a high standard of specification, suitability of purpose and meticulous capacitor engineering, and they satisfy the exacting demands of the British Postal Authorities whom we are proud to number amongst our customers. Full details and technical service upon request.

DUBILIER CONDENSER CO. (1925) LTD., DUCON WORKS, VICTORIA ROAD, N. ACTON, LONDON, W.3.

'Phone: Acorn 2241 (5 lines). Cables: Hivoltcon, London. Marconi International Code. 'Grams: Hivoltcon, Wesphone, London.

D

VALUABLE FREE BOOK

Tells You How to Pass Your C. & G. or Promotion Exam. at *First* Attempt!

All Post Office Engineering personnel who are anxious to obtain early promotion should at once send for a copy of our handbook "**ENGINEERING OPPORTUNITIES**," which, among other intensely interesting matter, describes our unique methods of preparation for **TECHNICAL APPOINTMENTS IN THE POST OFFICE** (Assistant Engineer—New Style and Assistant Traffic Superintendent), **CITY AND GUILDS EXAMINATIONS** in Principles of Telecommunications (1-5), Radio (1-4), Telephone Exchange Systems (1-3), Telegraphy (1 and 2), Line Transmission (1 and 2), Lines Plant Practice (1 and 2), Mathematics for Telecommunications (1-5), Electrical Engineering Practice (Prelim. Inter. and Final), and outlines a wide range of non-examination courses in all branches of **Electrical, Mechanical, Civil, Automobile, Aeronautical and Radio Engineering.**

Assistant Engineer and Assistant Traffic Superintendant. Open competitions now resumed. Age extensions for established Civil Servants. Ask us for full details

We definitely guarantee "NO PASS—NO FEE"

If you intend to make the most of to-day's opportunities, you cannot afford to miss reading "**ENGINEERING OPPORTUNITIES.**" It tells you everything you want to know to secure advancement, and describes many opportunities you may now be missing through lack of information. Send for your copy to-day—**FREE** and without obligation.

BRITISH INSTITUTE OF ENGINEERING TECHNOLOGY
369 SHAKESPEARE HOUSE, 17-19 STRATFORD PLACE, LONDON, W.1

BIET

PITMAN'S
for Technical Books

★

Industrial Electrical Plant Maintenance

By E. G. Anness, M.I.E.E., Chartered Electrical Engineer. Deals fully with D.C. and A.C. motors and their associated control and protective gear, and with transformers and capacitors as far as they affect the works engineer. 88 illustrations. 27/6 net.

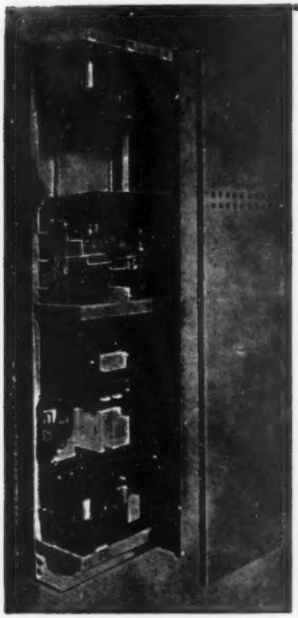
Telephony (2 vols.)

By J. Atkinson, A.M.I.E.E., Area Engineer, Post Office Engineering Dept. The standard textbook for post office engineers and students. Over 1,500 illustrations. Vol. I (General Principles and Manual Exchange Systems), 35/- net. Vol. II (Automatic Exchange Systems), 50/- net.

Telecommunications Principles

By R. N. Renton, A.M.I.E.E. A new work covering the syllabus for the City and Guilds examinations in Telecommunications Principles, Grades I, II and III. Illustrated. 37/6 net.

PITMAN, *Parker Street, Kingsway, London, W.C.2*



The Mark II series of

SAVAGE AMPLIFIERS
for Broadcast Relay

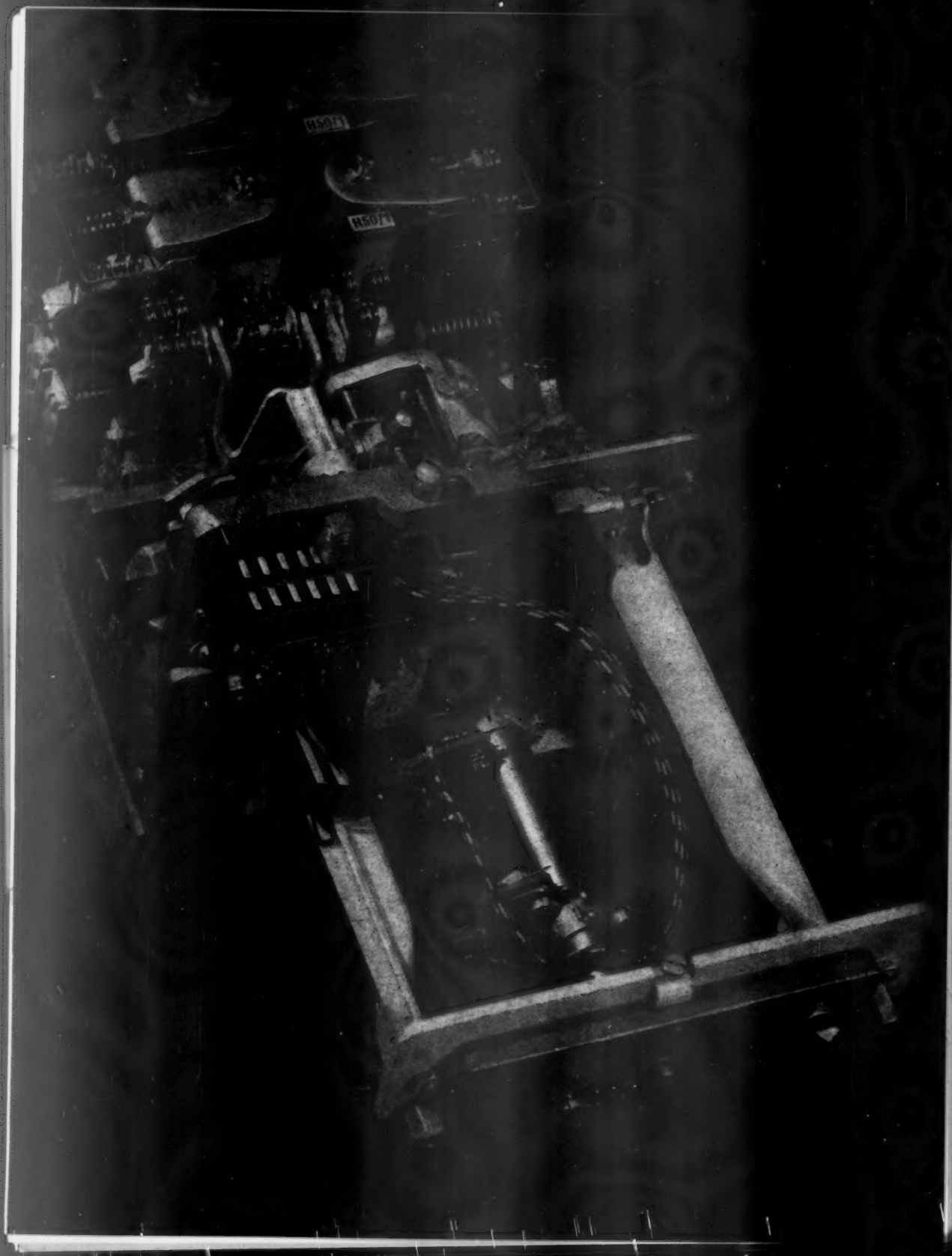
● These Amplifiers are examples of what careful design can achieve. A lift-off back panel affords immediate access for maintenance purposes and the removal of six screws releases the side covers of the rack and exposes all the interpanel wiring. Even when the rack is sandwiched between others the side covers can be removed just as easily.

All valves are accessible from the front of the rack, and are protected by quick release grilles. The rack is completely flat fronted. The general appearance is further enhanced by the absence of a projecting front foot, and the masking of all panel fixing bolts. Similar racks carrying auxiliary apparatus can be placed side by side with amplifiers so that the whole installation is uniform in appearance.

Complete specifications available on request.

WESTMORELAND ROAD
LONDON N.W.9
TELEPHONE: COLINDALE 7131

W. BRYAN SAVAGE LIMITED



A TELEPHONE SWITCHING SYSTEM AND MECHANISM THAT HAVE FOR FIFTY YEARS DEFIED COMPETITION

Half a century has elapsed since the selecting mechanism embodying Strowger's principle of step-by-step decimal selection proved practical in service. Throughout this period there has been intense technical development on systems competitive with the Strowger System, but the Strowger System has always remained pre-eminent. It is to-day the most widely used in the world, standardized by the British Post Office, which has recently reaffirmed its confidence in the Strowger System, and adopted by the operating administrations of more than 70 countries.

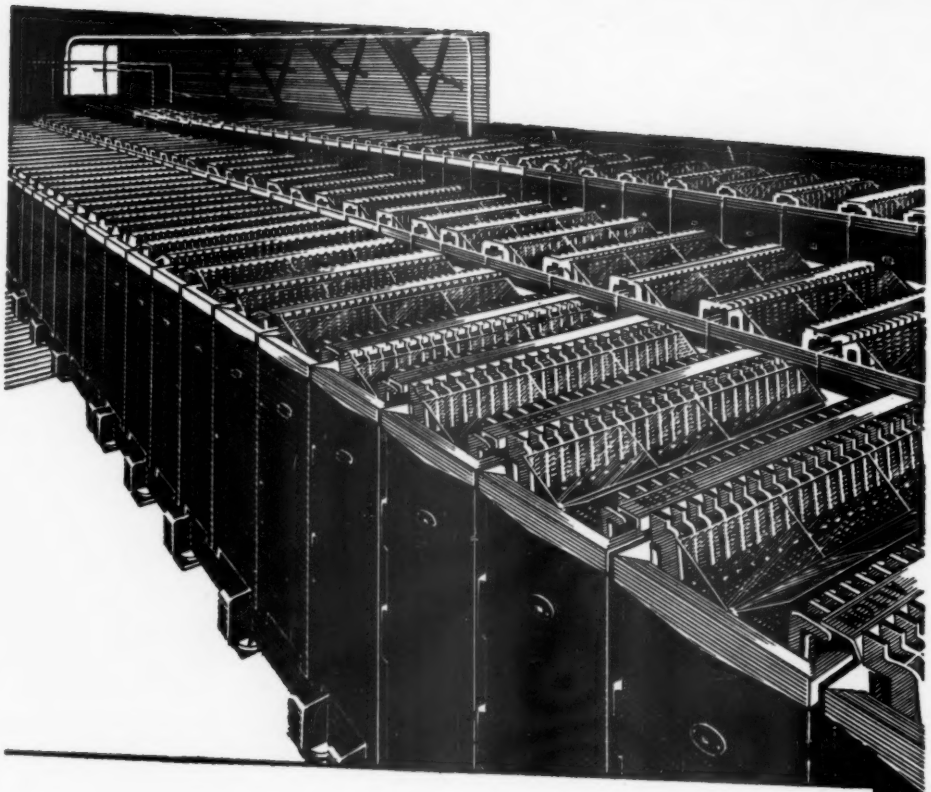
The increasing demand for automatic telephone service created a need for more and more equipment facilities, particularly in respect of operating speed and bank capacity. About 1930, therefore, Automatic Telephone & Electric Co. Ltd. investigated the possibilities of alternative systems and mechanisms with a view to meeting this demand. After prolonged and intensive research the company decided, and in the light of modern requirements still maintains, that a two motion mechanism embodying vertical and rotary motion and operated on a step-by-step decimal basis represents the best method of fulfilling the complex and varied requirements of automatic switching. The type 32A Selector, introduced in 1935, retained the operating principle characteristic of previous Strowger Selectors, but possessed marked advantages in speed, capacity, size, weight and adaptability. It was standardized by the British Post Office in that year as the type 2000.

During the past fifteen years every functional improvement which has been suggested during fifty years' operating experience with the Strowger System in all parts of the world has been incorporated in the Selector, which in future will be known as Type 32A Mark II.

Automatic Telephone & Electric Co. Ltd.

EXPORT DEPARTMENT : STROWGER HOUSE, ARUNDEL STREET, LONDON, W.C.2.
TELEPHONE : TEMple Bar 9262. CABLEGRAMS : STROWGEREX, LONDON.
STROWGER WORKS, LIVERPOOL, ENGLAND.

A7711-AZ104



Alton Batteries of 10 to 15,000 ampere-hours are in service in sixty-five countries. The batteries now being shipped out all over the world will carry the name of Alton still further afield—Alton, shortest word in any language for good batteries and firm delivery dates.

*

Alton can also supply renewal plates for all makes of battery, British and Continental.

ALTON

BATTERIES OF MERIT

THE ALTON BATTERY COMPANY LIMITED, Alton, Hampshire · Telephone: Alton 2267 and 2268 · Telegrams: Battery, Alton

THE RECTIFIERS *for* TELECOMMUNICATION

Undoubtedly the most dependable source of D.C. power supply, Westinghouse metal rectifiers are applied extensively in communication engineering, where absolute efficiency and reliability is essential. Employed in telephone and telegraph circuits, they are used either for charging the batteries of the apparatus or operating it direct from A.C. mains. They are installed in transmitting and receiving stations, and numerous other applications include spark quenching, rectifying voice and radio frequency currents and for polarising and slugging standard relays in telephone and telegraph circuits.

WESTINGHOUSE

METAL RECTIFIERS

Write for Publication M.R.9 to Dept. P.O.E.E.J. 4.

WESTINGHOUSE BRAKE & SIGNAL CO. LTD. 82, York Way, King's Cross, London, N.1

DECADE RESISTANCES

in 3 Grades guaranteed

0·01% 0·03% 0·1%

SUPPLIED BOXED OR FOR CLIENT'S OWN PANEL

HIGHLY LAMINATED BRUSHES

LOWER DECADES OF ABSOLUTELY CONSTANT INDUCTANCE

EQUALLY SUITABLE FOR HIGH FREQUENCY LOW FREQUENCY OR DIRECT CURRENT

H. W. SULLIVAN

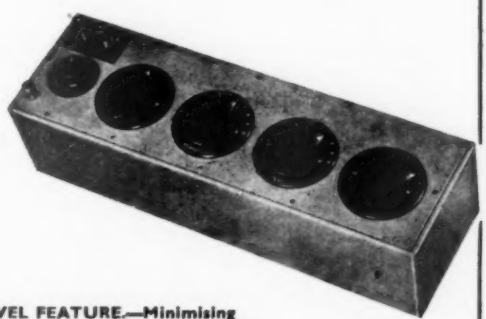
— LIMITED —

LONDON, S.E.15

Telephone : New Cross 3255 (P.B.X.)

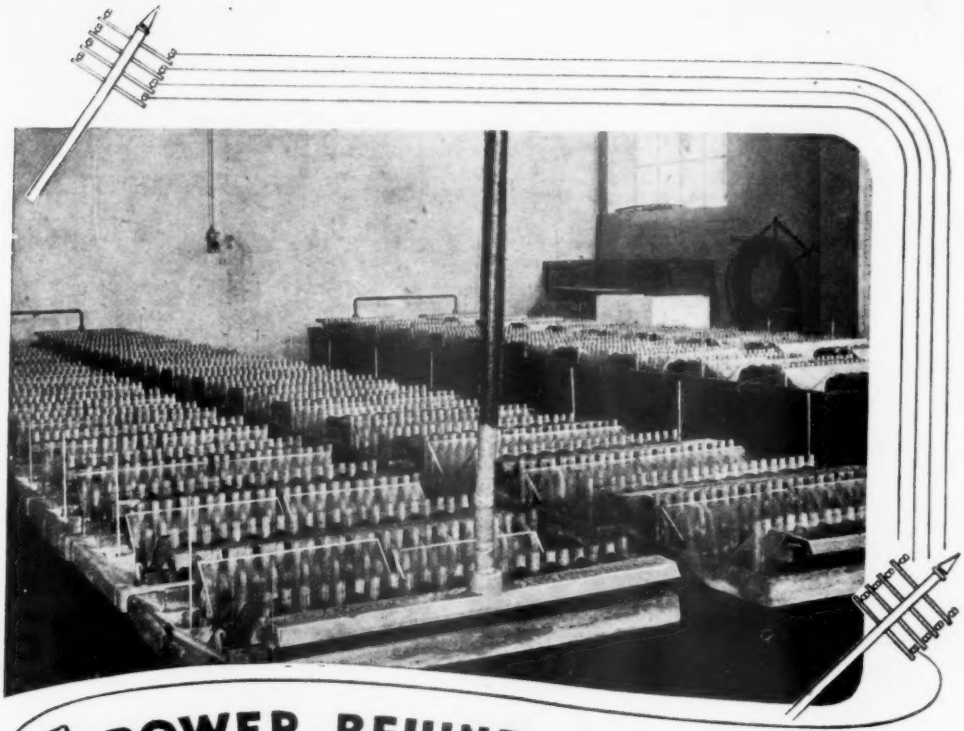
Electrical Standards for Research and Industry

Testing and Measuring Apparatus for Communication Engineering



A NOVEL FEATURE.—Minimising the Residual Inductance and High Frequency Resistance Error.

A patented method of reactance compensation is employed on the higher decades which compensates automatically for the screen capacitance and so renders the effective **residual inductance sensibly independent of the method of screen connection.** In addition, the user may, at will by the simple operation of a switch, adjust the reactance or resistance error sensibly to zero at the higher frequencies.



POWER BEHIND THE LINES

TUNGSTONE PLANTÉ CELLS are being supplied to the British Post Office and Post and Telegraph Departments in many countries overseas. They conform fully to G.P.O. and British Standard specifications.

OPEN TYPE CELLS

Similar to the illustration above, these are available in glass and/or lead lined wooden boxes in capacities from 100 a.h. to 500 a.h.

ENCLOSED TYPE CELLS

As illustrated on the right, these are in moulded glass boxes with sealed-in lids. Capacity range from 10 a.h. to 200 a.h.

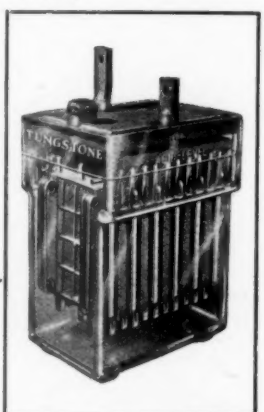
REPLATALS

We are in a position to supply plates for the replating of any existing Planté Battery.

HIGH VOLTAGE TELEPHONE BATTERIES

Portable Type. Standard layout for 50 volts, in waxed hard wood crates, exactly to the requirements of the G.P.O.

Overseas customers are invited to cable or write their enquiries for batteries or parts. Visitors to London are welcome at our offices.



TUNGSTONE *Batteries*

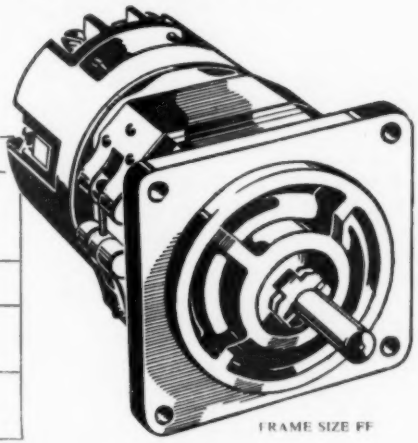
For further particulars write : **TUNGSTONE PRODUCTS LIMITED**
10 SALISBURY SQUARE · LONDON · E.C.4 · ENGLAND. Cables: "Dilutum" London.

T.B.12

EVERSHED

SPECIAL DUTY F.H.P. MOTORS

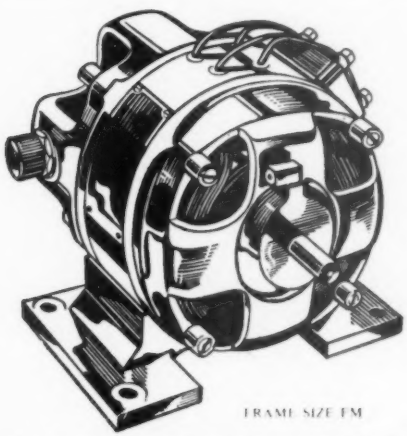
TYPICAL D.C. MOTORS AND GENERATORS



FRAME SIZE FF

MOTORS

FRAME SIZE	DETAILS
FP	1/100 H.P. D.C. motor. Series or shunt for constant speed (2,000 r.p.m.). Wound for voltages 20, 110 or 220 volts with limiting resistor.
FQ	As FP, but with approx. 50% increased output.
FM	1/20 H.P. D.C. motor. Series or shunt wound. Voltages 20-220 volts. Speeds 2,000-4,000 r.p.m.
FF2	1/100 H.P. Permanent magnet D.C. motor. Wound for voltages 20-110 volts.



FRAME SIZE FM

GENERATOR

FRAME SIZE	DETAILS
FF1	Permanent magnet D.C. generator for speed measurement and electronic control. Output 25V. per 1,000 r.p.m. Moment of inertia 0.5 oz. ins^2. Ripple 1½% R.M.S. of generated voltage. Driving torques: 0 r.p.m. 0.75 oz. ins. 6,000 r.p.m. 2.5 oz. ins.

Send for the Evershed Small Motors' Data Book, X22

EVERSHED AND VIGNOLES LIMITED

ACTON LANE WORKS · CHISWICK · LONDON · W4

Telephone: Chiswick 3670 *Telegrams: Megger, Chisk, London* *Cables: Megger, London*

5/166

WIDE-BAND EQUIPMENT

H.F. panels at Huntington Repeater Station, near Cannock, on the Birmingham-Manchester television link.

The H.F. panels, one for each direction of transmission, both mount two amplifier units, one in service and one as a standby. The amplifier units equalise each repeater section to within ±0·1 db between 60 kc/s and 4·34 Mc/s, and have a gain of 52 db at 4·4 Mc/s.

□ □ □ *The largest British electrical*

for radio and coaxial links

London - Birmingham
Birmingham - Manchester
and now
London - Cardiff

The first television service in the provinces of the U.K. was relayed to the Sutton Coldfield transmitter by the London-Birmingham wide-band U.H.F. radio link, which was designed, manufactured and installed by the G.E.C. The next transmitter to come into service (at Holme Moss, near Manchester) will receive vision signals from Birmingham over coaxial tubes for which the G.E.C. is supplying wide-band amplifiers to a design by the British Post Office. Soon a third link, between London and Cardiff, will include similar amplifiers now in production at the G.E.C. Telephone, Radio and Television Works, Coventry.

G.E.C.

The General Electric Company Ltd. of England. Telephone, Radio and Television Works, Coventry, England. Telephone Coventry 4111 (10 lines) Telegrams and Cables "Springjack, Coventry." Head Office, Magnet House, Kingsway, London, W.C.2. Temple Bar 8000 (90 lines) "Electricity, Westcent, London." Cables, "Polyphase London."

manufacturing organisation in the world

Creed
TELEPRINTERS

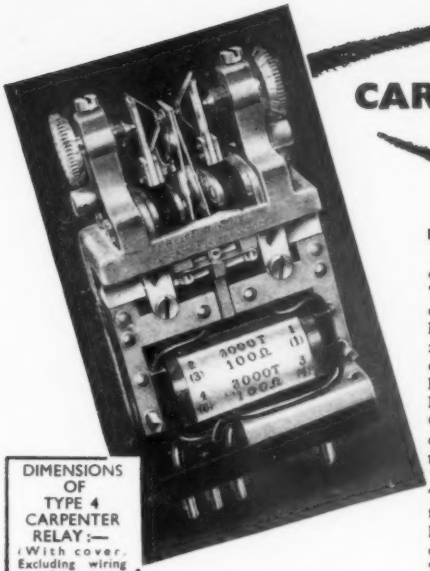
Built by specialists in machine telegraphy~

N° 47 TAPE MODEL

Write for Bulletin N° 21

Creed & Company Limited

TELEGRAPH HOUSE
CROYDON, ENGLAND



DIMENSIONS OF TYPE 4 CARPENTER RELAY:— (With cover. Excluding wiring tags) 3.5 ins. high x 2.2 ins. wide x 1 in. deep. Weight 13 ozs

CARPENTER POLARIZED RELAY

TYPE 4

THIS is a medium speed, sensitive polarized relay designed primarily as a telephone impulsing relay (D.C. dialling up to 100 miles and V.F dialling on trunk circuits). It has also been successfully adopted for use in Telex systems, but can be used satisfactorily up to speeds of 100 c/s without contact chatter or serious bias disturbances.

Its sensitivity is such that when the gap is adjusted to .004 in. nominal, the relay will just operate at 50 cycles with 3.5 ampere-turns R.M.S. (corresponding to approximately 2 mVA) or on 4.5 D.C. ampere-turns at low speeds. In service, however, the relay is normally operated at currents substantially larger than the minimum operating current quoted.

Contact chatter is absent if the contact gap does not exceed .005 in. The contact gap is adjustable by means of fine pitch screws with knurled heads marked with .001 in. divisions. Contacts on the armature tongue are insulated from it and thereby from the frame.

The relay has a magnetic screening cover with transparent removable top to facilitate contact adjustment.

Dimensionally the relay is interchangeable with the type " 3000 " relay and can be supplied to fit directly to the drilling normally provided for the " 3000 " relay.

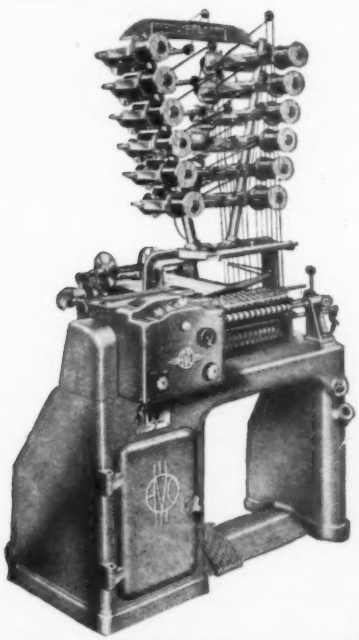
Termination can either be made by means of a 12 in. plug base as illustrated, or with soldering tags in place of the pins.

Developed & Manufactured by the Sole Licencees:— *Complete details available on request.*

TELEPHONE MANUFACTURING COMPANY LTD.

Contractors to the British Commonwealth and Foreign Governments

HOLLINGSWORTH WORKS • DULWICH • LONDON, S.E.21 *GIPsy Hill 2211 (10 lines)*

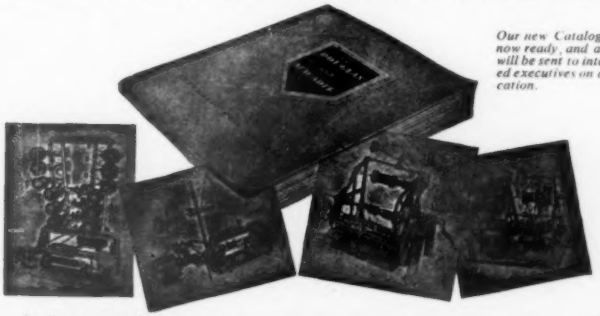


DOUGLAS AND MACADIE

Automatic

COIL WINDERS

The large illustration depicts the improved "Douglas" Fully Automatic Multi-Winder, specially developed for the high-speed production of large quantities of coils with or without paper interleaving. It will produce round, square or rectangular coils up to 6 in. each in length and up to 4½ in. diameter. As many as 12 smaller coils can be wound simultaneously within the total available winding length of 12 in. at headstock speeds of between 600 and 2,000 r.p.m.



Our new Catalogue is now ready, and a copy will be sent to interested executives on application.

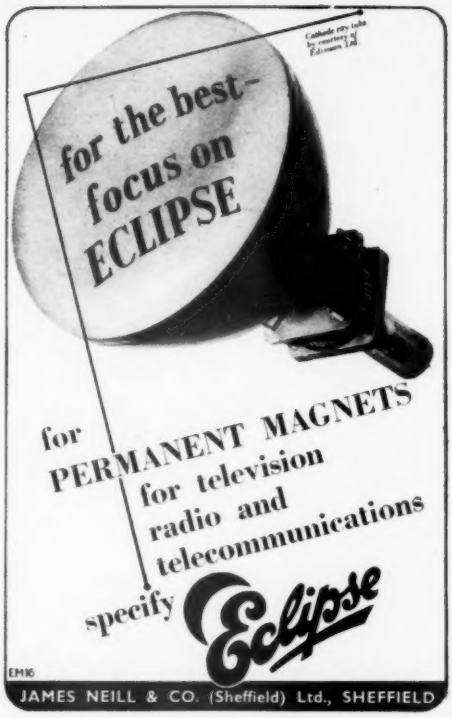
Sole Proprietors and Manufacturers:

The AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT CO. LTD.

WINDER HOUSE • DOUGLAS STREET • LONDON • S.W.1 *Telephone: VICTORIA 3404/9*

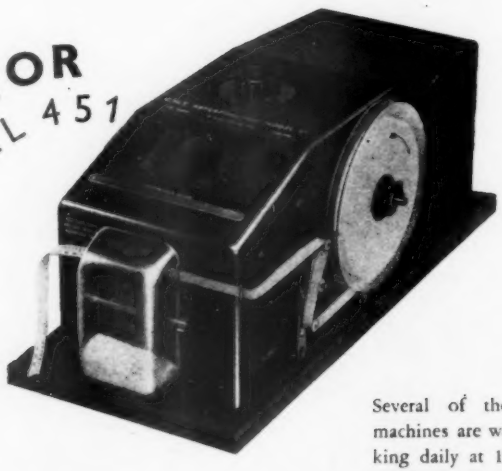
INDEX TO ADVERTISERS

	PAGE
Airmec Laboratories, Ltd.	xxiii
Alton Battery Co., Ltd., The	xiv
Automatic Coil Winder & Electrical Equipment Co., Ltd.	xxi
Automatic Telephone & Electric Co., Ltd.	xii-xiii
Bennett College, The	ii
Berco	ii
British Institute of Engineering Technology	xi
British Power Transformer Co., Ltd.	iii
Creed & Co., Ltd.	xx
Dubilier Condenser Co. (1925), Ltd.	x
Edison Swan Electric Co., Ltd., The	iii
Ericsson Telephones, Ltd.	vi
Evershed & Vignoles, Ltd.	xvii
Ferranti, Ltd.	iv
General Electric Co., Ltd., The	xviii-xix
Great Northern Telegraph Co., Ltd.	xxii
Hackbridge Cable Co., Ltd.	vii
International Correspondence Schools, Ltd.	xxiii
Marconi's Wireless Telegraph Co., Ltd.	v
Muirhead & Co., Ltd.	vii
Neill, James, & Co., Ltd.	xxii
Painton of Northampton	xxiv
Pirelli-General Cable Works, Ltd.	xxiv
Pitman, Sir Isaac, & Sons, Ltd.	xi
Savage Transformers	ii
Savage, W. Bryan, Ltd.	xi
Siemens Brothers & Co., Ltd.	viii-ix
Smith, Frederick, & Co.	ii
Sullivan, H. W., Ltd.	xv
Telephone Manufacturing Co., Ltd.	xxi
Tungstone Products, Ltd.	xvi
Turner Electrical Instruments, Ltd.	iv
Westinghouse Brake & Signal Co., Ltd.	xv
Winn & Coales, Ltd.	xxiii



G.N.T.

REPERFORATOR
MODEL 451



A truly synchronous reperforator for morse code.

Speed range:
40-200 words per minute without gear changes.

Supplied with A. C. or D. C. motor as required.

Several of these machines are working daily at 180 words per minute.

☆ *Write for comprehensive catalogue.*

THE GREAT NORTHERN TELEGRAPH COMPANY's FACTORY

4, SYDHAVNS PLADS
COPENHAGEN SV . DENMARK

★

LONDON OFFICE: 5, ST. HELENS PLACE
LONDON E.C.3.

Denso

PERMANENTLY PLASTIC PROTECTION

gives **3-FOLD** Protection for all Metalwork above or below ground.

Denso Permanently Plastic Tape seals pipes, mains, cables and all metal structures—exposed or buried—from the menace of chemical and electrolytical corrosion.

Indispensable for sealing cable ends—the temporary repair of fractured gas-mains—and a real aid to frostproofing.

Full technical details of Denso Anti-corrosive and Sealing Products gladly supplied.

WINN & COALES LTD.

DENSO WORKS, CHAPEL ROAD, LONDON, S.E.27.

Telephone : GiPsy Hill 4247/8. Telegrams : Densolte, Westnor, London.

SOUND INSTRUCTION by Postal Method

The I.C.S., largest school in the world devoted to spare-time training by the postal method, offers you highly specialised Courses for the following examinations:

P.M.G. Certificates for Wireless Operators.
C. & G. Illumination Engineering (Inter.)
C. & G. Electrical Engineering Practice, Installation and Telecommunications.
Graduateship of the B.I.R.E.

I.C.S. Examination students are coached till successful.

Other Courses meet the requirements of all who desire to qualify for responsible positions in Electric Power, Illumination, Heating and Traction Systems. Equally successful is our instruction for Telegraph and Radio Engineers, Radio Servicemen, and in Elementary Radar and Electronics, Advanced Short-Wave Radio and Television Technology.

Instruction is by correspondence from textbooks specially prepared by many experts.

WRITE FOR OUR SPECIAL BOOKLET and state the particular subject or Examination in which you are interested.

YOU MAY USE THIS COUPON

International Correspondence Schools Ltd.
Dept. 108, International Buildings, Kingsway, London, W.C.2

Please send me, free of charge, your special booklet on.....

Name ..... Age .....
(Block Letters, Please)

Address .....

.....

ICS

H.F. SIGNAL GENERATOR TYPE 701

30 kc/s — 30 Mc/s

AIRMEC

THE use of a two-valve tuned buffer stage which operates on all ranges of this Signal Generator, enables an excellent output waveform to be obtained from 30 kc/s-30 Mc/s. This arrangement also reduces spurious frequency modulation occurring with amplitude modulation to a very low level, and ensures that the oscillator frequency remains independent of the setting of the output and attenuator controls.

An automatic gain control circuit maintains the output voltage level constant within ± 1 db over the whole frequency range, and a negative-feedback modulation circuit ensures a constant modulation depth and pure modulation envelope waveform under all circumstances.

Illustrated descriptive leaflets of this or any other Airmec instrument will be gladly forwarded upon request.

AIRMEC LABORATORIES LTD

HIGH WYCOMBE · BUCKINGHAMSHIRE · ENGLAND

TEL: HIGH WYCOMBE 2060 CABLES: AIRMEC, HIGH WYCOMBE

TELEPHONE CABLES

OUR TELECOMMUNICATION CABLES CATALOGUE, GIVING INFORMATION AND SPECIFICATIONS FOR A WIDE RANGE OF TELECOMMUNICATION CABLES MANUFACTURED BY US, IS AVAILABLE UPON REQUEST.

TELEPHONE: SOUTHAMPTON 2141 (5 lines).

PIRELLI-GENERAL
CABLE WORKS, Ltd., SOUTHAMPTON.

TELEGRAMS "PIGEKAYBEL SOUTHAMPTON

ACTUAL SIZE

TECHNICAL DATA

CAT. Nº 200150

Inductance	17·3 microhenries
Resistance (d.c.)	7·4 ohms.
Self Capacity	11·3 pF
Q at self resonant frequency	64
Self resonant frequency	36 Mc/s
Dynamic Resistance at 36 Mc/s	250 K ohms.

CAT. Nº 200151

Inductance	2·3 microhenries
Resistance (d.c.)	0·4 ohms.
Self Capacity	6·5 pF
Q at resonant frequency	290
Self resonant frequency	63 Mc/s
Dynamic resistance at 63 Mc/s	264 K ohms.

THE NEW HIGH 'Q' MINIATURE H·F CHOKE

ANOTHER FINE EXAMPLE OF....

Control by PAINTON

PAINTON & CO., LTD., KINGSTHORPE NORTHAMPTON
PHONE: NORTHAMPTON 2320
GRAMS: CEIL NORTHAMPTON

Printed by SANDERS PHILLIPS & CO., LTD., The Baynard Press, Chryssell Road, London, S.W.9. and Published by BIRCH & WHITTINGTON (*Prop. Darling & Co. [Epsom], Ltd.*,) Epsom, Surrey.